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QUEST FOR THE HIGH GROUND:
THE DEVELOPMENT OF SEAD STRATEGY

BY

MAJOR DANIEL BALTRUSAITIS

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The conclusions and opinions expressed in this document are those of the author. They do not reflect the official position of the US Government, Department of Defense, the United States Air Force, or Air University.

About The Author

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Abstract

The danger of surface-to-air defenses grows as the nature of US conflicts continues to change. Ground based defenses promise attrition while forcing air forces into standoff range. Furthermore, ground-based defenses cost less and require less training than airborne systems; definite advantages for third world adversaries. Coalition performance in the Gulf War showed future adversaries that they would suffer tremendously by trying to match symmetrically US airpower capability. US strategists should expect enemy systems in the future aimed at causality sensitivity in situations where US vital interests are not at stake. These issues illuminate the need to make defense suppression a planning priority to ensure air superiority.

Although air superiority relies on defeating both the air-to-air and surface-to-air defense, this study examines only one element in the quest for air superiority -- the suppression of enemy air defenses (SEAD). This study determines how SEAD operational objectives change with the nature and maturity of an air campaign..

This research logically flows through three phases to illustrate and categorize SEAD objectives and strategy. First, phase is a historical review of suppression operations significant to US strategy development from W.W.II to the present, focusing on enduring truths that emerge concerning suppression operations. This examination of suppression's role concentrates on how airpower adjusted to the recurring measure-countermeasure struggle. Of particular importance is the evolution of suppression theory and doctrine. Focus of the review is the development of the concepts of opportune, localized, and campaign SEAD.

The second phase provides an analysis of ground-based defense employment and functions. Systems based on centralized, semi-autonomous, and autonomous control were analyzed. Identifying highly dependent subsystems offers the potential for inducing cascading effects or significant system disruption. Analysis of these three air defense control methods, shows inherent strengths and weaknesses depending on the nature of control and type of SEAD operations.

The third phase is an evaluation of the components of airpower that comprise SEAD capability. This study focuses on the value of knowledge in the conduct of SEAD by examining commander preferences using a value model to understand how the nature of the threat, and the maturity of the air campaign, change the significance of knowledge. Value modeling, or multi-attribute analysis, allows a quantification of preferences by separating them into attributes with defined measures of merit and utility. The value model clearly highlights the elementary factors that facilitate the gathering of information for defense suppression. Motivation for building and evaluating the SEAD model was to lend some insight into the mission's complexity, while complementing the commander's intuitive thinking.

The study of SEAD history, air defense systems, and value modeling, is to emphasize to the strategist the nuances of SEAD airpower application throughout the duration of an air campaign.

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Chapter 1

Introduction

The gaining of air superiority is the first requirement for the success of any major land operation....In this way only can destructive and demoralizing air attacks against land forces be minimized and the inherent mobility of modern land and air forces be exploited to the fullest.

Field Manual 100-20, July 1943

Air superiority is the single most influential element in deciding the outcome of modern conventional war. Command of the air is also an essential operational enabler in military operations other than war. Airpower theorists from Giulio Douhet to Col. John Warden emphasize the primacy of air superiority.¹ Gaining it is not an end in itself; achieving air dominance is useful only with the ability and will to exploit it. Air superiority is no more than a means to an end, providing the opportunity for direct attack on enemy centers of gravity.²

Air superiority is not an abstract quality espoused merely by airpower theorists, but is also stressed in joint and service doctrine. Joint doctrine also stresses its importance. Joint Pub 3-0, *Doctrine for Joint Operations*, states that air and maritime superiority enable and enhance joint operations and should normally be attained early in a campaign.³

Surface based air defenses are one of the most serious threats to gaining and maintaining air superiority. In combat, they account for significantly more than half of the total threat to establishing air superiority.⁴ In every war since World War I, ground defenses killed more American aircraft than fighters.⁵ Depending on the conflict, ground-based defenses account for 50-88% of US aircraft losses.⁶ Although these percentages

are high, it is important to consider that overall attrition rates have substantially declined since World War II.⁷ Unfortunately, even with reduced attrition, surface-based defenses provide a major obstacle to gaining and exploiting air superiority.⁸

The danger of surface-to-air defenses grows as the nature of US conflicts continues to change. According to James Dunnigan in *How to Make War*, the demise of Soviet air forces has eliminated the most serious threat to US air superiority, placing the burden of defense on ground based guns and missiles.⁹ Ground based defenses promise attrition while forcing air forces into standoff range.¹⁰ Furthermore, ground-based defenses cost less and require less training than airborne systems; definite advantages for third world adversaries. Coalition performance in the Gulf War showed future adversaries that they would suffer tremendously by trying to match symmetrically US airpower capability. US strategists should expect enemy systems in the future aimed at causality sensitivity in situations where US vital interests are not at stake. These issues illuminate the need to make defense suppression a planning priority to ensure air superiority.

Although air superiority relies on defeating both the air-to-air and surface-to-air defense, this study examines only one element in the quest for air superiority -- the suppression of enemy air defenses (SEAD). This study determines how SEAD operational objectives change with the nature and maturity of an air campaign. Motivation is to capture rationale and logic used to determine SEAD priorities and objectives providing a useful source document for planners and analysts.

Significance

Although the USAF has shown constant improvement in defense suppression capability, little experience is codified outside the classified arena to aid defense suppression study. USAF operational level suppression doctrine is virtually non-existent, leaving the planner to search through tactical manuals to determine basic suppression strategy.¹¹ Air Force Doctrine Document 10, *Counterair Operations*, addresses the importance of SEAD for combat operations, but provides little guidance on planning SEAD operations.¹² Multi-Command Manual (MCM) 3-1 Series manuals provide

tactical guidance to mission planners, but offers less guidance for strategy development. In addition, the classification of MCM 3-1 stifles the open discussion of defense suppression practices. Although Joint Doctrine provides an excellent foundation for understanding SEAD, it falls short in providing a framework for analyzing and formulating suppression strategy. This study provides a framework for developing a comprehensive SEAD strategy, as part of an overall air operation, by isolating objectives and sub-objectives that illustrate what makes SEAD a success.

Basic Concepts

SEAD is a subset of the offensive counterair (OCA) mission aimed at neutralizing enemy ground based air defenses. SEAD, as defined by Joint Pub 3-01.4, is any activity that neutralizes, destroys, or temporarily degrades air defenses by destructive or disruptive means. SEAD, like air superiority, is not an end to itself, but creates favorable conditions for all friendly air operations.¹³ SEAD operations fall into three categories: Campaign SEAD, localized suppression, and opportune suppression. Campaign SEAD¹⁴ creates increasingly favorable conditions for friendly operations by disabling enemy air defense systems, producing long term theater wide effects. Localized suppression, normally with specified time and space limitations, supports specific operations or missions. Opportune suppression includes self-defense and offensive attacks against enemy air defense targets of opportunity.¹⁵

Additionally, SEAD methods are defined as either destructive or disruptive. Destructive operations ensure the long term degradation of enemy air defenses by destroying the target system or operating personnel. The effects are cumulative and increase overall survivability, but may place large demands on available combat forces. Destructive measures predominate in campaign SEAD. Disruptive means, on the other hand, seek to temporarily deny, degrade, deceive, delay, or neutralize enemy air defense systems to increase aircraft survivability.¹⁶ Disruption is typically seen in localized operations. Opportune SEAD could be either destructive or disruptive depending on aircraft weapon load and objectives.

Measures closely related but not classically defined as SEAD include electronic mutual support. Electronic warfare (EW) includes command and control warfare, radar jamming, and electronic protection. EW is an inseparable protection measure while attempting to suppress enemy air defenses.¹⁷

Methodology

This research logically flows through three phases to illustrate and categorize SEAD objectives and strategy. First, phase is a historical review of suppression operations significant to US strategy development from W.W.II to the present, focusing on enduring truths that emerge concerning suppression operations. Emphasis is on operations that had an impact on USAF suppression development. This examination of suppression's role concentrates on how airpower adjusted to the recurring measure-countermeasure struggle. Of particular importance is the evolution of suppression theory and doctrine. Focus of the review is the development of the concepts of opportune, localized, and campaign SEAD in comparison to the nature of air defense command and control.

The second phase provides an analysis of ground-based defense employment and functions. Basic air defense structure and functions provide a framework for systems analysis. This systems analysis identified highly dependent subsystems, or functions, throughout the air defense system by rating their importance to overall system performance. Identifying highly dependent subsystems offers the potential for inducing cascading effects or significant system disruption. Analysis of three air defense control methods, shows inherent strengths and weaknesses depending on the nature of control and type of SEAD operations.

The third phase is an evaluation of the components of airpower that comprise SEAD capability against projected threats. This study focuses on the value of knowledge in the conduct of SEAD by examining planner preferences using a value model to understand how the nature of the threat, and the maturity of the air campaign, change the significance of knowledge. Value modeling, or multi-attribute analysis, allows the decision-maker to weigh preferences by separating them into attributes with defined

measures of merit and utility. This approach develops an analysis technique that links qualities and quantities into a single model.¹⁸ The value model clearly highlights the elementary factors that facilitate the gathering of information for defense suppression. As a serendipity, the particular value-model chosen illustrates one means of codifying, quantifying, and using these elementary factors to highlight value tradeoffs throughout the various stages of a SEAD operation. The ultimate purpose, though, is to emphasize to the strategist the nuances of airpower SEAD application throughout the duration of an air campaign.

Limitations

This study aims at tearing air defense systems and air suppression capabilities apart, exposing the very essence of what makes SEAD effective. The study's scope limits access to classified material. It omits national intelligence information and classified military studies so that the paper can remain unclassified. Open sources such as *Jane's Information Group* and *Journal of Electronic Defense* provided information concerning air defenses and specific weapons systems capability. Open access will allow a wider readership and open dissemination of the ideas presented.

Additionally, the SEAD was completely value-modeled for only the knowledge oriented tasks. To completely understand the complexity and performance tradeoffs that a commander must make, the entire SEAD mission should be modeled. Time and space constraints limited this study to only information oriented tasks.

Notes

¹ One failure of the Douhet theory is that he overstated air superiority's impact. Douhet wrote that the independent air force, exploiting command of the air, would be condition enough to cause victory in war. Giulio Douhet, *The Command of the Air*, trans. Dino Ferrari, (1942; new imprint, Washington D.C.: Office of Air Force History, 1983), 98-99.

² For a discussion of an airman's view of air superiority see Col. P. S. Meilinger, "Achieving Air Superiority: Issues and Considerations," *Air Power Supplement, The Royal Air Force Magazine*, 1996, 6-12.

³ Joint Pub 3-0, *Doctrine for Joint Operations*, 1 February 1995, IV-5.

⁴ John Knowles and Zachary Lum, "Into the Readiness Gap," *Journal of Electronic Defense* 19, no. 9 (March 1996), 49.

Notes

⁵ Kenneth P. Werrell, *Archie, Flak, AAA, and SAM: A short Operational History of Ground-Based Air Defense*, (Maxwell AFB, AL: Air University Press, December 1988), 177.

⁶ Ibid., 42, 74-75, 102, 118. Maj Paul Burbage, et. al., "The Battle for the Skies Over North Vietnam," USAF Southeast Asia Monograph Series, Vol 1, Monograph 2, 107-188. Eliot A. Cohen, et. al., *Gulf War Airpower Survey*, Vol 5, A Statistical Compendium and Chronology, (Washington D.C.: Government Printing Office, 1993), 641.

⁷ US attrition rate to AAA was less than 2% in the European theater during WWII. Robert Frank Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force 1907-1960, Volume I*, (Maxwell AFB, AL: Air University Press, 1989), 156. Air Force, Marine Corps and Navy flak losses of 1,087 aircraft on 736,439 sorties in Korea amounted to a rate of 0.15%. Werrell, 74-75. Attrition to surface defenses for the Gulf War was approximately .045% *Gulf War Airpower Survey*, Vol 5, 651.

⁸ Even with reduced attrition rates, the political impact of one downed aircraft can be staggering. Depending on the political nature of the conflict one failure may have immense consequences on conflict execution. Maj Gen John Corder (Ret), CENTAF Deputy for Operations during Desert Storm, interviewed by author, 15 April 97.

⁹ James F. Dunnigan, *How to Make War: A Comprehensive Guide to Modern Warfare for the Post-Cold War Era*, 3rd ed., (New York: William Morrow and Company, Inc., 1993) 199.

¹⁰ One of the more interesting studies of the Gulf War is by Brig V.K. Nair, *War in the Gulf: Lessons for the Third World*, (New Delhi: Lancer International, 1991) which aims at asymmetric strategies for defeating US dominance.

¹¹ Maj Bruce Gebhard, "Putting the 'J' in J-SEAD," (SAMS Monograph, US Command and General Staff College, AY93-94), 27.

¹² Air Force Doctrine Document 10, *Counterair Operation*, Final Draft, (Washington D.C.: Department of the Air Force, 1 September 1996), 20.

¹³ Joint Pub 3-01.4, *Joint Tactics, Techniques, and Procedures (JTTP) for Joint Suppression of Enemy Air Defenses*, 25 July 1995, I-1.

¹⁴ This study uses the term Campaign SEAD versus the joint term Area of Responsibility (AOR)/Joint Operations Areas (JOA) Area Defense Suppression for two reasons. First, Campaign SEAD is the common terminology at the user level and in many technical and professional journals. Second, the Joint Staff acronym hides the intent of the area suppression effort. Area suppression is a large campaign, or operation, aimed at neutralizing the defense system as a whole. The joint staff AOR acronym does not make this distinction clear.

¹⁵ Joint Pub 3-01.4, I-1.

¹⁶ Ibid., I-6.

¹⁷ Ibid., I-7.

¹⁸ Frank B. Strickland, Jr., "It's Not About Mousetraps -- Measuring the Value of Knowledge for Operators," *Joint Force Quarterly*, no. 13 (Autumn 1996), 91-92.

Chapter 2

SEAD Development

Doctrine is a codified set of beliefs on what has usually worked best in the past. It is a compilation of experiences, or lessons, to shape the mind of the commander while providing a foundation for strategy, tactics, and training.¹⁹ SEAD doctrine contained in Joint Pub 3-01.4, *Joint Tactics Techniques and Procedures (JTTP) for the Joint Suppression of Enemy Air Defenses*, records the suppression lessons necessary for the employment of airpower against surface defenses and provides a framework for strategy development. This section traces the development of SEAD operations, and provides a historical background for understanding the nature of SEAD and its doctrine.

Overview

Air Force suppression development was slow initially due to a lack of adequate equipment and doctrine. Early methods to protect aircraft from ground-fire were mostly reactive. Efforts to neutralize antiaircraft artillery (AAA) from the air were largely ineffective due to inaccurate fire against entrenched ground defenses, but coordinated artillery fire against AAA proved somewhat effective. AAA countermeasures such as chaff and high-altitude avoidance predominated, but bombing accuracy and effectiveness suffered. The Korean war saw a continuance of the suppression struggle. Unfortunately, the USAF took two years to develop joint suppression techniques similar to those used in the close of W.W.II. Since the W.W.II lessons were not codified, crewmembers had to relearn them through experience.

USAF involvement in Vietnam, and the introduction of an effective surface to air missile spurred the service into taking defense suppression more seriously. SAM threats

forced the USAF, and other services, into a more proactive approach towards ground defenses. The USAF developed effective techniques at countering SAMs, but due to political constraints these efforts remained localized. The first true SEAD campaign effort was Linebacker II, but it developed as a reaction to high aircraft losses, not as a necessary condition for beginning the offensive air campaign.

The Israeli experience also provided many lessons to the USAF in developing suppression tactics. The Yom Kippur War of 1973 showed the effectiveness of SAMs in denying air superiority and the effectiveness of joint air/ground operations. Bekka Valley in 1982, displayed the effectiveness of campaign SEAD in the opening minutes of an air operation. Additionally, it highlighted the synergistic effects of training and intelligence.

Desert Storm showed the efficacy of campaign SEAD combined with a persistent application of localized and opportune suppression. A swift theater wide SEAD application effectively neutralized the Iraqi air defense system in the opening minutes of the war. SAM sites were further suppressed and harassed through a continuing series of smaller SEAD efforts. SEAD effectively neutralized the significant threat posed by Iraqi ground defenses.

Early Theory

Despite the effectiveness of AAA in W.W.I,²⁰ postwar airpower doctrine surprisingly neglected efforts to neutralize ground defenses. Apparently, rapid aircraft advancements in speed and altitude overcame the effectiveness of artillery advancement and caused airpower advocates to discount the effectiveness of enemy ground defenses. Giulio Douhet, the father of early strategic airpower theory, minimized the impact of the World War I lessons. Not foreseeing the advent of radar, he theorized that aviation flexibility made ground defenses obsolete.²¹ In the United States, Brigadier General William “Billy” Mitchell advocated a similar proposition -- observing that ground defenses waste limited defense dollars.²² He believed advances in aircraft technology far outweighed advances in AAA.²³ Although Mitchell advocated AAA as a small part of a layered defense, he discounted the effectiveness of AAA alone against striking aircraft.

The Army Air Force (AAF) entered World War II believing in the survivability of bombers against defenses. Although this belief was not universal, AAF doctrine showed little concern for the effect of AAA on bomber missions.²⁴ Bomber success assumed inadequate ground reaction time, giving the aircraft the advantage of surprise. They presumed static defenses, condemning the adversary to an inherently weak defense everywhere. The introduction of radar mitigated the advantage of surprise, making air defenses much more potent.

Lessons Relearned: World War II and Korea

World War II

Both the Allies and Axis attempted active suppression efforts during the war, but passive efforts, such as chaff and avoidance, remained more effective in protecting against AAA.²⁵ The Germans attempted the first use of campaign SEAD during the Battle of Britain. The Luftwaffe attempted to destroy British early warning radar sites during early phases of the battle to “knock out the enemy's eyes,” but they soon discontinued the apparently unsuccessful attacks. However, unknown to the Luftwaffe, these attacks actually put significant stress on the British air defense system and further efforts could have crippled the British air defense.²⁶ IX Tactical Air Command enjoyed some success in localized flak suppression with Army Ground Forces artillery, but altitude, avoidance, and maneuver remained more effective tactics.²⁷ Air suppression efforts in support of operation Market Garden (a three division airborne assault behind German lines in 1944) were less successful. Flak suppression succeeded on the first day of the operation, but losses mounted as the Germans countered Allied tactics. Allies lost 104 aircraft to flak on a total of 4,320 sorties (2.4%), but more disturbing, of those 104 lost, 37 were on the 646 suppression sorties (5.7%). A U.S. Strategic Air Forces in Europe report after Market-Garden listed air suppression as ineffective, and concluded that alternate measures were more practical.²⁸ These measures, altitude, evasive maneuvers, chaff, and ECM were more effective by forcing the Germans to use degraded firing modes, decreasing AAA accuracy.²⁹

World War II confirmed that AAA, coupled with radar, was hazardous to aircraft operations, counter to the Mitchell and Douhet theories. In the European theater, from August 1942 to May 1945, the AAF lost 4,274 planes to enemy aircraft fire and 5,380 to AAA fire. Masking the significance of AAA fire was the fact that total losses were less than 2 percent of total sorties -- apparently American leaders accepted this as the price of doing business.³⁰ Allied airmen knew that flak was a problem, but active suppression was costly in terms of lives and mission effectiveness; subsequently, passive measures prevailed.

Korea

The Korean War saw little advancement from W.W.II in the ability to suppress AAA. Korea had neither the quantity of AAA nor the integration of warning devices seen in Germany, but was still able to significantly hinder U.S. operations. United States Far Eastern Air Forces (FEAF) initially saw flak as ineffective in denying air superiority. Unfortunately, hostile ground fire necessitated high altitude operations, reducing bombing accuracy. Although the U.S. maintained air superiority, they required more sorties to destroy a target. The loss rate to AAA was a minimal 0.17 percent, but out of 1,230 U.S. losses, all but 143 were due to ground fire.³¹ Again, the low attrition rate masked the effectiveness of AAA. Although 5th Air Force considered these aircraft combat losses acceptable, flak damage placed a severe burden on combat capability. General Glenn O. Barcus, 5th Air Force Commander, and Admiral J.J. Clark ordered a 3,000 foot minimum altitude to reduce AAA damage. The increased recovery altitude caused an appreciable decrease in bombing accuracy.³² Americans learned that AAA could still hinder air superiority exploitation.

USAF attempts at localized suppression, in Korea, were a response to rising losses and not from any study W.W.II experience. The Air Force took two years to establish coordinated air-ground tactics similar to those used in W.W.II.³³ The Air Force and Army finally combined for operation SUPPRESS to subdue flak near front-line operations. These combined arms attacks reduced aircraft losses despite heavy AAA concentration in the IX Corps region. During a one month experiment, the USAF lost only one aircraft on 1,816 close air support sorties (CAS) compared to planning figures of

one loss per 380 CAS sorties.³⁴ Operation SUPPRESS showed the effectiveness of joint army-air operations in targeting enemy defense positions.

The Air Force entered Korea with but minor respect for AAA, but eventually saw the need to develop tactics directly against it. Commanders could more effectively counter surface defenses by applying the lessons of World War II. The Korean experience showed that AAA was still dangerous. AAA effectively degraded FEAF bombing performance by forcing formations to bomb at night, in poor weather, or from high altitude. Additionally, sortie effectiveness diminished due to the need to focus 5 to 15 percent of a strike effort towards localized defense suppression. Precision guided munitions development began to provide more effective bombing from the sanctuary outside AAA range.³⁵ Overall, American forces left the Korean theater with the same increased respect for flak that they had after World War II, using virtually the same approaches. Unfortunately it took them several years to relearn these tactics. Once again, no concerted post-war doctrinal effort was devoted to SEAD.

The Genesis of Modern SEAD: Vietnam and The Yom Kippur War

Vietnam

On 24 July 1965, the nature of air combat changed significantly with the downing of a USAF F-4C by a Vietnamese SA-2.³⁶ Although SA-2s had already shot down two American U-2 reconnaissance aircraft, tactical forces over Vietnam were unprepared to handle this new threat. Prior to the introduction of surface-to-air missiles (SAMs) in Vietnam, suppression strategy remained basically unchanged since W.W.II. With the introduction of SAMs, the sanctuary of altitude no longer protected aircraft from surface-based defenses. Until July 1965, the U.S. maintained air superiority through a conventional effort against NVA MIG-15s while conceding the lowest altitudes to the North's AAA. SAMs, on the other hand, denied the U.S. high sanctuary and drastically increased the effectiveness of AAA by driving aircraft to lower altitudes where SAMs were ineffective.³⁷ With these resources, the Vietnamese affected the U.S. air campaign in two significant ways. First, SAMs forced U.S. aircraft to fly inside the AAA range

reducing weapons accuracy while increasing aircraft vulnerability.³⁸ Second, attacks on highly defended targets were costly. AAA and small weapons fire downed a total of 455 aircraft by the end of 1966.³⁹ Flak alone accounted for 132 fixed wing losses in 1965, and accounted for 66 percent of U.S. losses in the North, from 1965-1973.⁴⁰ The subsequent U.S. transition to low-level daylight operations to avoid SAMs increased AAA effectiveness, and showed the difficulty in exploiting air superiority in a SAM environment.⁴¹

Political limitations imposed by the Defense Department precluded campaign SEAD against the integrated defenses as a whole. General William Westmoreland, U.S. Military Assistance Command Commander, stated that John McNaughton, Assistant Secretary of Defense for International Security Affairs, deemed the SA-2 introduction as a Soviet political ploy that would not be used against U.S. aircraft.⁴² This assessment politically limited Westmoreland from attacking SA-2 sites, unless for self-defense, for fear of a wider confrontation with the Soviets. Because of those restraints, rules of engagement never allowed attack on the entire integrated defense system.⁴³ Air planners adopted a localized suppression strategy instead of removing the entire integrated defense threat using a SEAD campaign. NVA SAMs and AAA therefore continually challenged U.S. air superiority.

Localized suppression methods flourished because of the restrictions on wider efforts. More effective active suppression efforts emerged against SAMs, complementing the already established passive electronic countermeasure (ECM) measures. The U.S. initially used “Iron Hand” and “Wild Weasel” tactics to suppress the SAM threat to strike packages. Wild Weasels were F-100, F-105G, and finally F-4G aircraft outfitted with electronics to accurately detect, discriminate, and target hostile radars. Weasel aircraft disabled or neutralized threat emitters with anti-radiation missiles.⁴⁴ Iron Hand missions, on the other hand, conventionally bombed SAM sites located by the Wild Weasels. The purpose of an Iron Hand mission was to decoy and disable SAMs, allowing an associated strike package to reach the target area.⁴⁵

Localized suppression missions were dangerous and required persistent application during a strike. The NVA turned SA-2 sites into AAA traps to lure the Iron

Hand missions; crews considered the missions extremely hazardous.⁴⁶ However, General William W. Momyer, 7th Air Force Commander, while acknowledging the difficulty in assessing suppression effectiveness, credits success to the number of unengaged strike flights with Iron Hand missions in the area.⁴⁷ U.S. aircraft also implemented preemptive launch of anti-radiation missiles to keep SAM radars off-line while strike aircraft transited. This tactic proved fairly effective with no instances of illumination and damage from a preempted SAM site from April to October 1972.⁴⁸ Localized and opportune suppression proved effective in protecting strike packages.

A reduction of political restrictions in 1972 finally allowed the U.S. to conduct campaign SEAD. U.S. strikes against SAM sites, the mining of Haiphong harbor, and high intensity air attacks in tactical and strategic air campaigns resulted in the exhaustion of the North's defensive capability. After suffering heavy B-52 losses on the first five nights of the campaign, the U.S. launched a concerted SEAD effort against the IADs on 26 December. Tactical aircraft attacked individual SAM sites and radars, while B-52s and F-111s targeted SAM storage sites.⁴⁹ From 14 December to 29 December 1972, the North Vietnamese launched 1,285 SAMs that downed 15 B-52s and three other aircraft, but by 29 December they ran out of SAMs, leaving the country defenseless from air attack.⁵⁰ An integrated, massive campaign made the North's ground defenses ineffective.

Efforts toward air control in the Vietnam conflict changed the character of air warfare. Aircraft could no longer depend on the sanctuary of altitude unless SAMs were neutralized. Due to political constraints, the USAF initially countered with localized SEAD efforts. Target area defenses were suppressed to protect individual packages, but these efforts increased the requirement for support aircraft. By the end of Linebacker II, the USAF saw the benefits of a campaign suppression strategy. The integrated attacks against SAM storage, radars, and launch sites had a synergistic effect of dismantling North Vietnamese defenses. These efforts were finally highlighted in Air Force basic doctrine. The 1971 version of Air Force Manual (AFM) 1-1 for the first time addressed the need for SEAD.⁵¹

Yom Kippur War

Events in the Sinai in 1973 again highlighted the need for a systematic approach to SEAD. Egypt and Syria attacked Israel on two fronts to impose on her a limited defeat. Arab strategy aimed at involving the superpowers in a negotiated settlement to reclaim territory lost in the '67 war.⁵²

Since the Egyptian Air Force had failed to protect the Army in the previous Six Day War (1967), the Army planned an armored offensive that would move only under the protection of a counterair missile umbrella. To protect assault forces, air defenses deployed in echelon using fixed SA-2 and SA-3 sites to provide protection for western Sinai forces, mobile SA-6 SAMs to provide forward coverage, and radar aimed ZSU-23 AAA to defend against low-flying aircraft.⁵³ This protective envelope inflicted serious losses on the IAF.⁵⁴ From October 6th to the 9th, Arab air defenses shot down more than 50 IAF aircraft.⁵⁵ Complacency derived from their stellar success in 1967 caused the IAF to neglect SEAD and rely mainly on ECM for protection. Although the IAF used ECM equipment of U.S. design, they found it obsolete against newer generation defenses. The Israelis appreciated the threat of newer SA-6s and SA-8s, but overestimated their ability to deal with them. As a result, they used mainly Iron Hand tactics to destroy SAM sites.⁵⁶ High losses and SAM density caused the IAF to pull back from these direct attacks, effectively, rendering bombing imprecise.⁵⁷ The density of mobile air defenses covering the troops provided an effective air umbrella that facilitated offensive ground operations.

Israel eventually countered Egyptian and Syrian SAMs through a combined arms approach of mass and concentration.⁵⁸ On the Syrian front, Israel used artillery fire to disable SA-6 batteries, creating holes for IAF exploitation. Aircraft destroyed air defense command and control sites but still sustained fairly heavy losses.⁵⁹ On the Egyptian front, the bloody forward thrust of Egyptian armies allowed Israeli forces to counterattack into the Egyptian rear. Once behind the Egyptian Army, Israeli 175mm artillery and mobile forces destroyed four SAM sites.⁶⁰ This opening achieved, the IAF destroyed 40 of the 55-60 SAM batteries in action. Contrary to conventional practice, ground forces made air superiority possible.

The Vietnam and the Yom Kippur wars showed the potential of ground defenses in denying air superiority by providing a lethal protective umbrella. Both air forces entered their respective conflicts with a localized SEAD doctrine; SAMs and AAA would be handled individually to protect aircraft in a package. ECM and anti-radiation missile shooters organized to facilitate limited strike package objectives. After the wars, doctrine in the U.S. shifted towards a methodical approach in targeting air defenses. The 1984 edition of AFM 1-1 cited SEAD as equal in importance to offensive and defensive counterair.⁶¹ As a sub-set of air superiority, a concerted effort towards the *systemic* destruction of air defenses gained favor in facilitating the entire air campaign.

Offensive SEAD Campaigns: Bekaa Valley and Desert Storm

Bekaa Valley

Nearly 10 years after the Yom Kippur War, the IAF once again went into large scale action in southern Lebanon. On 9 June 1982 a new era of SEAD began with an Israeli air campaign aimed at the Syrian defenses in the Bekaa Valley. The success of the campaign hinged on the outstanding preparation for the event. The IAF attack against Syrian SA-6 sites executed a combined arms plan that stressed planning, intelligence, training, command and control, and practice.⁶² Israeli forces used miniature remotely piloted vehicles (RPVs) to detect and fix the location of Syrian SA-6 sites and emitters.⁶³ The IAF spent nearly a year simulating strikes against mock SA-6 sites in the Negrev Desert to develop effective tactics and coordination.⁶⁴ Israel entered the campaign with a clear understanding of the threat and a logically developed doctrine to counter it.⁶⁵

Israel achieved surprise using speed, mass and deception to overcome Syrian defenses. Boeing 707 and CH-53 helicopter standoff jammers disrupted Syrian radar and communications.⁶⁶ High speed drones stimulated the SA-6 sites into activity while “Scout” mini-RPVs passed real time targeting back to airborne command aircraft.⁶⁷ When SA-6 sites revealed their locations firing at the drones, RPV-aimed artillery fire harassed those sites. IAF strike aircraft continued the attack with anti-radiation missiles,

standoff munitions, cluster bomb units, and general purpose bombs.⁶⁸ In this brief, yet intense attack the IAF destroyed 17 of 19 SAM sites without the loss of a single aircraft.⁶⁹

The Israelis showed that intelligence, planning, command and control, speed, and mass could turn a campaign oriented SEAD doctrine into a highly effective offensive strategy. The successful SEAD campaign, combined with offensive counterair against Syrian MIGs, produced Israeli air superiority. The integration of artillery attacks with air strikes, coordinated by an airborne command post with real-time intelligence, showed the synergistic effect of synchronized joint operations.⁷⁰ The Bekaa Valley SEAD campaign, though limited in scope, marked a shift from a tactical package protection to an operational campaign doctrine. It showed the potential of campaign SEAD when aimed at high payoff systems.

Desert Storm

Desert Storm, like the Bekaa Valley campaign, showed the dominance of airpower, when predicated upon effective SEAD. The early success of the initial SEAD effort helped achieve of air superiority. With their air defenses neutralized, the Iraqis suffered under the full weight of allied airpower.⁷¹ Lt Gen Charles A. Horner, Joint Force Air Component Commander (JFACC), chose to strike air defense command and control as his primary objective in obtaining air superiority.⁷² The “absolute necessity of suppression of enemy air defenses” and “increased survivability through timely use of electronic combat” achieved this objective.⁷³ Additionally, Maj Gen John Corder, CENTAF Deputy for Operations, stated his primary objective was to dominate the defenses with a massive attack that would paralyze the system.⁷⁴

The Allied Coalition defeated the Iraqi Air Defense Force and gained absolute control of the air. The Iraqis directed the integrated air defenses (IADs) from Baghdad through the Air Defense Force (IADF). It controlled fighters, SAMs, and AAA guns with a highly centralized system of command and control.⁷⁵ Coalition intelligence analysis of Iraq’s defense capabilities highlighted their over-centralization. This particular employment doctrine weakness was crucial in the development of an effective SEAD strategy.⁷⁶

In the opening minutes of Desert Storm, the unrelenting SEAD application destabilized and then destroyed Iraqi air defenses. After the first 20 minutes of the war, the Iraqi IADs were ineffective even though most of its infrastructure was intact because command and control elements could not communicate.⁷⁷ The SEAD effort was a truly joint effort. Army Apache helicopters attacked early warning radar sites in western Iraq, F-117 stealth fighters struck operations centers, and Navy cruise missiles pounded air defense command and control.⁷⁸ With the IADs blinded and air defense command and control degraded, the Allies targeted individual SAM sites. Standoff jamming confused the radars while drones stimulated sites into attack. Once sites targeted the drones with radar, coalition aircraft launched over 200 high speed anti-radiation missiles (HARM) to disable them.⁷⁹ As daylight arrived, conventional munitions attacks concentrated on SAM sites, radars, and air defense facilities.⁸⁰ The cumulative result of this effort allowed Allied aircraft to operate with impunity at medium to high altitudes.⁸¹ The sanctuary stolen by SAMs in Vietnam was unequivocally recovered. Additionally, U.S. precision guided munitions (PGM) capability allowed it to more effectively use the high sanctuary -- making the SEAD success all the more significant.

Coalition ability to achieve mass, surprise, and shock critically aided the SEAD attack. They concentrated the appropriate mass to quickly disable and destroy Iraqi air defense targets.⁸² Stealth and cruise missile technology allowed the allies to achieve surprise and seize the initiative.⁸³ Iraqi integrated air defenses crumbled under the surprise and shock from the intensity of attack.

Despite highly successful SAM suppression efforts, manportable (MANPAD) infra-red (IR) SAMs and AAA remained a deadly threat.⁸⁴ NATO doctrine reflected the tradeoff in trying to suppress defenses in the dense European threat environment,⁸⁵ and instead stressed low altitude ingress and weapons delivery. In the Gulf War, British forces suffered an especially high aircraft attrition employing weapons designed specifically for low altitude. The British Tornado force lost ten percent of its aircraft to AAA and MANPADS by flying low-altitude maneuvers.⁸⁶ Overall, AAA and infra-red SAMs killed 22 out of the 38 aircraft lost in direct enemy action.⁸⁷ Although AAA was dangerous at low altitudes, PGMs allowed the coalition to effectively target from the

safety of higher altitudes. AAA/MANPADs alone could no longer degrade bombing accuracy.

Summary

Airpower history provides some enduring truths, and rules of thumb to consider while countering ground based defenses. These truths are codified in Joint Publications for guiding future air campaign actions. This section traced the early attempt at campaign SEAD, and the localized methods that followed. The advent of the SAM showed the need to more proactively neutralize surface-based air defenses. Campaign SEAD eventually was possible with the introduction of more capable weapon systems and limited political constraints. To effectively counter surface defenses all three types of SEAD operations (campaign, localized, and opportune) are necessary, depending on the weapons system capability and political will.

The most significant conclusion of this historical study is the underestimation of the ability of short range air defenses (AAA/MANPADs) to affect air control. In every war since World War I, more American aircraft have been lost to AAA than to enemy fighters. The USAF has developed tactics and equipment that limits air-to-air losses to near zero. Hopefully, improved anti-radiation missiles, stealth, and precision guided munitions will provide the same advantage against surface defenses. The most important factor in decreasing losses to short range air defenses (SHORAD) is operating from medium to high altitudes. World War II, Korea, Vietnam, and the Gulf War proved that low-level operations against SHORAD defended threats is costly. Surprise and one-pass attacks limited AAA capability, but avoidance by altitude was the single most effective defense. Active AAA suppression was sometimes effective, but the low altitude losses usually drove these operations to medium altitudes. More effective SHORAD measures were avoidance and joint attack operations.

Second, joint operations proved highly successful in suppressing enemy air defenses. Artillery strikes in Korea, ground forces attack on SA-6s in the Sinai, Bekka Valley, and Desert Storm showed the synergism of joint operations. Surface-based air

defenses are optimized to defend against aircraft, providing a vulnerable target for ground and artillery attack.

Third, electronic warfare (EW) and SEAD are inseparable. The synergistic effects of SEAD and EW are boldly seen in both the Bekaa Valley and Desert Storm campaigns. SEAD and EW compliment each other in comparison to overall objectives. To gain the most impact from these assets they should be singularly managed when used as part of a defense suppression strategy.

Finally, intelligence is crucial to the effective defense suppression. Bekaa Valley and Desert Storm highlight the importance of developing a pre-war order of battle, combined with real-time threat information. The Six-Day war is equally telling of the surprises possible with lack of adequate intelligence. Proper intelligence allows the appropriate targeting of critical nodes, and allows strikes the greatest chance of success. Inadequate intelligence causes the planner to be reactive to threats, countering with whatever is available, rather than proactive, countering with the best weapon. Due to the importance of SEAD in gaining air superiority, intelligence gathering through national assets down to theater controlled RPVs should be of highest priority.

Notes

¹⁹ Maj Gen I.B. Holley, Jr., USAFR (Ret), "A Modest Proposal: Making Doctrine More Memorable," *Airpower Journal* IX, no. 4 (Winter 1995), 18-19.

²⁰ AAA was fairly affective on the Western Front; German gunners claimed 1,588 Allied aircraft kills, the French claimed 500, the Italians 129, the British Expeditionary Force 341, and the U.S. 58. Kenneth P. Werrell, *Archie, Flak, AAA, and SAM: A Short Operational History of Ground-Based Air Defense*, (Maxwell AFB, AL: Air University Press, 1988), 1.

²¹ Giulio Douhet, *The Command of the Air*, trans. Dino Ferrari, (1942; new imprint, Washington D.C.: Office of Air Force History, 1983), 18.

²² William Mitchell, *Winged Defense: The Development and Possibilities of Modern Air Power Economic and Military*, (1925; reprint, New York: Dover Publications, Inc., 1988), 206.

²³ *Ibid.*, 213.

²⁴ Several exercises were conducted during the 1930's using Maj Claire Chennault's early warning system of ground observers, telephones, pursuit aircraft, and AAA defenses. Although deemed fairly effective, the prevailing thought was that more could be gained by spending directed at offensive airpower capability. In addition, the new XB-17 was expected to fly over all but the heaviest caliber of AAA. Maurer Maurer, *Aviation in the U.S. Army, 1919-1939*, (Washington D.C.: Office of Air Force History, 1987), 413-420.

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²⁵ “Flak versus Heavy Bombers,” *The Coast Artillery Journal* LXXXIX, no. 2 (March-April 1946), 24-25

²⁶ The problem of evaluation effectiveness against electronic systems continues today. Although the Luftwaffe effectively degraded the British radar net, they had no valid method to measure outcomes other than reduced aircraft losses. To the German pilot, the destruction of a single radar site was of minimal value because he noticed no decrease in preparedness by the RAF. Williamson Murray, *Strategy for Defeat: The Luftwaffe 1933-1945*, (Maxwell AFB, AL: Air University Press, 1983), 50. Robin Higham, “The Royal Air Force and the Battle of Britain,” in *Case Studies in the Achievement of Air Superiority*, ed. Benjamin Franklin Cooling, (Washington D.C.: Center for Air Force History, 1994), 129.

²⁷ Major General Elwood R. Quesada, “Effect of German Antiaircraft Artillery on IX Tactical Air Command Operations,” *The Coast Artillery Journal* LXXXIX, no. 5 (September-October 1946), 29-30.

²⁸ Werrell, 45.

²⁹ “Flak versus Heavy Bombers,” 24-25.

³⁰ Robert Frank Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force 1907-1960, Volume I*, (Maxwell AFB, AL: Air University Press, 1989), 156

³¹ Air Force, Marine Corps and Navy combat losses of 1,230 aircraft on 736,439 sorties amounted to a rate of 0.17 percent. Werrell, 74-75.

³² Robert Frank Futrell, *The United States Air Force in Korea 1950-1953*, (1981, reprint, Washington D.C.: Center for Air Force History, 1983), 519.

³³ Werrell, 80-81.

³⁴ *Ibid.*, 79-80.

³⁵ The Navy initiated the BULLPUP guided missile program in direct response to its losses to ground fire in Korea. David R. Mets, *Nonnuclear Aircraft Armament: The Quest for a Surgical Strike, The United States Air Force and Laser Guided Bombs*, (Eglin AFB, FL: Office of History, Armament Division, Air Force Systems Command, 1987), 43-48.

³⁶ “SAMs Down F-4C, Damage Three Others,” *Aviation Week and Space Technology*, 2 August 1965, 27.

³⁷ Thomas C. Hone, “Southeast Asia,” in *Case Studies in the Achievement of Air Superiority*, ed. Benjamin Franklin Cooling, (Washington D.C.: Center for Air Force History, 1994), 528-531.

³⁸ Aircraft were forced to maneuver heavily on bomb runs to avoid hostile AAA fire, reducing the time spent on a stable bomb run.

³⁹ Carl Berger, ed. *The United States Air Force in Southeast Asia, 1961-1973: An Illustrated Account*, (Washington, D.C.: Office of Air Force History, 1984), 82.

⁴⁰ Werrell, 102-103.

⁴¹ Lt Col James R. Brungress, *Setting the Context: Suppression of Enemy Air Defenses and Joint War Fighting in an Uncertain World*, (Maxwell AFB, AL, 1994), 6.

⁴² General William C. Westmoreland, *A Soldier Reports*, (Garden City, N.Y.: Doubleday & Company, 1976), 120.

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⁴³ General William W. Momyer, *Air Power in Three Wars (W.W. II, Korea, Vietnam)*, (Washington DC: Department of the Air Force, 1978), 118.

⁴⁴ Maj William A. Hewitt, *Planting the Seeds of SEAD: The Wild Weasel in Vietnam*, SAAS Thesis, (Maxwell AFB, AL: Air University Press, 1993), 8-18. Hone, 553.

⁴⁵ Momyer, 131.

⁴⁶ James D. Crabtree, *On Air Defense*, (Westport, Conn: Praeger Publishers, 1994), 137.

⁴⁷ Momyer, 131-132.

⁴⁸ Hewitt, 18.

⁴⁹ Brungress, 9. Although direct attacks were made at the SAM system, actual strikes on SAM sites themselves were relatively ineffective due to poor weaponeering against portable targets. The defenses most likely disintegrated due to a lack of SAMs to replace the massive quantity launched at bomber formations. Interdiction of missile supply and change of B-52 egress tactics had a cumulative effect on reducing NVA defense capability. Herman L. Gilster, *The Air War in Southeast Asia: Case Studies of Selected Campaigns*, (Maxwell AFB, AL: Air University Press, 1993), 90-93, 112. Earl H. Tilford, *Setup: What the Air Force Did in Vietnam and Why*, (Maxwell AFB, AL: Air University Press, 1991) 256-262.

⁵⁰ Werrell 125-126.

⁵¹ Active suppression measures are mentioned for the first time as a counterair function in AFM 1-1, *Basic Air Force Doctrine*, 28 September 1971.

⁵² Chaim Herzog, *The Arab-Israeli Wars: War and Peace in the Middle East from the War of Independence through Lebanon*, (New York: Vintage Books, 1982), 227-230.

⁵³ Crabtree, 152.

⁵⁴ Brereton Greenhous, "The Israeli Experience," in *Case Studies in the Achievement of Air Superiority*, ed. Benjamin Franklin Cooling, (Washington D.C.: Center for Air Force History, 1994), 528-531.

⁵⁵ Lon Nordeen, *Fighters Over Israel*, (New York: Orion Books, 1990), 146.

⁵⁶ Greenhous, 585-586.

⁵⁷ Lon Nordeen, *Air Warfare in the Missile Age*, (Washington D.C.: Smithsonian Institution Press, 1985), 152. Greenhous, 590.

⁵⁸ Nordeen, *Air Warfare in the Missile Age*,

⁵⁹ Werrell, 144.

⁶⁰ Ibid., 144. Nordeen, *Fighters Over Israel*, 137-138. Greenhous, 594-595.

⁶¹ AFM 1-1, *Basic Aerospace Doctrine of the United States Air Force*, (Washington D.C.: Headquarters USAF, 1984), 3-3.

⁶² Maj David E. Clary, "EW in the Bekaa Valley: A New Look," *Journal of Electronic Defense* 13, no. 6 (June 1990), 36.

⁶³ Israeli Mastiff MKIII and Scout ELINT mini-RPVs were used extensively to locate and record sites and emitter characteristics to determine order of battle. John V. Cignatta, "A U.S. Pilot Looks at the Order of Battle, Bekaa Valley Operations," *Military Electronics/Countermeasures* 9, no. 2, 108-109. Paul S. Cutter, "Lt. Gen. Rafael Eitan:

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‘We Learned Both Tactical and Technical Lessons in Lebanon,” *Military Electronics/Countermeasures* 9, no. 2, 100.

⁶⁴ Clary, 37. CIC Matthew M. Hurley, “The Bekaa Valley Air Battle, June 1982: Lessons Mislearned?,” *Airpower Journal*, Winter 1989, 64-65.

⁶⁵ Some sources claim the war was due to threats to Israeli national security posed by SAMs. Israel trained specifically to remove this threat to national security. Paul S. Cutter, “ELTA Plays a Decisive Role in the EOB Scenario,” *Military Electronics/Countermeasures* 9, no. 1. (January 1983), 136

⁶⁶ Cignatta, “Lt. Gen. Rafael Eitan...,” 107.

⁶⁷ Cutter, 100. Clary, 38. Hurley, 64.

⁶⁸ Clary 38.

⁶⁹ Werrell, 147. Clary, 34.

⁷⁰ Benjamin S. Lambeth, “Moscow’s Lessons From the 1982 Lebanon Air War,” in *War in the Third Dimension*, ed. R.A. Mason, (McLean VA: Pergamon-Brassey’s International Defense Publishers, 1986), 133. Clary, 40.

⁷¹ Michael Armitage, “After the Gulf War,” *NATO’s Sixteen Nations* 36, Feb. 1991, 11.

⁷² Lt Gen Charles A. Horner, “The Air Campaign,” *Military Review*, no. 9 (September 1991), 21.

⁷³ *Ibid.*, 17.

⁷⁴ By January 1991, coalition planners had a fairly good idea of Iraqi IAD operations. They exploited their centralized command and control by targeting sector operations centers, leaving the system vulnerable to attack. Maj Gen John Corder, CENTAF Deputy for Operations, interview with author 15 April 1997.

⁷⁵ Crabtree, 172.

⁷⁶ Horner, 23. Lt Cmdr Gary B. Hicks, “Joint Suppression of Enemy Air Defenses During ‘Desert Storm’: Implications for Future Campaign Support J-SEAD Operations,” (master’s thesis, Naval War College, 1992), 9

⁷⁷ Brungress, 42.

⁷⁸ Thomas A. Keaney and Eliot A. Cohen, *Revolution in Warfare? Air Power in the Persian Gulf*, (Annapolis: Naval Institute Press, 1993), 283.

⁷⁹ *Ibid.*, 195, 284-285.

⁸⁰ *Ibid.*, 287. A-10s were used the first day to destroy early warning ground controlled intercept sites which were essentially undefended. Al Gershanoff, “EC in the Gulf War,” *Journal of Electronic Defense* 14, no. 5 (May 1991), 44.

⁸¹ Group Captain A G B Vallance, “The Gulf War: First Thoughts on the Use of Air Power in Crisis Management and Conflict,” *The Hawk*, 1991, 30-31.

⁸² European air forces favored smaller packets in the name of flexibility. Desert Storm showed the use of mass to concentrate the effects of firepower and saturate enemy defenses. Vallance, 31.

⁸³ The Soviet General Staff was highly impressed with the ability of cruise missiles to achieve strategic surprise in non-nuclear war. Mary C. Fitzgerald, “The Soviet Military and the New Air War in the Persian Gulf,” *Airpower Journal* V, no. 4, (Winter 1991), 73.

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⁸⁴ Radar SAMs were effectively neutralized by EW and SEAD, but aircraft remained especially vulnerable to AAA and man-portable IR SAMs. Stephen M. Hardy, "EW Shines in Gulf War Report," *Journal of Electronic Defense* 15, no. 7 (July 1992), 92-93.

⁸⁵ David J. Stein, *The Development of NATO Tactical Air Doctrine 1970-1985*, RAND Report R-3385-AF (Santa Monica, CA: December 1987), 46-47

⁸⁶ Six out of 60 operational aircraft were shot down employing JP 233 runway denial bomblets. The British later used Buccaneers to laser-designate targets for bombs dropped at medium altitudes for Tornados. Norman Friedman, "The Air Campaign," *U.S. Naval Institute Proceedings*, April 1991, 49. Vallance, 30-31.

⁸⁷ Keaney, 273.

Chapter 3

Air Defense Systems

Effective suppression of enemy air defense (SEAD) operations requires a comprehensive knowledge of the targeted air defense system. The Israeli Air Force success in the Bekaa Valley, and coalition air forces' achievement in the Gulf War showed the impact of in-depth target analysis on suppression effectiveness. On the other hand, the initial Israeli losses to Arab SA-6s in the Yom Kippur War show the danger of overconfidence. A clear understanding of the nature of the defense system, including critical nodes⁸⁸ and vulnerabilities, is key to disabling enemy ground defense systems.

An air defense system is the collection of personnel, sensors, weapons, and command, control, communication (C³) systems and processes that combine to detect and engage air threats. They provide destruction or neutralization of hostile air vehicles before they threaten forces and critical assets. Air defenses protect high value assets, strategic targets, key C³ nodes, and critical military units.⁸⁹ They perform the function of active air defense, by taking direct defensive action to destroy attacking air and missile threats or reducing their effectiveness against friendly forces and assets.

Air defenses are either active or passive. Active air defense is direct action to engage air and missile threats, reducing their effectiveness against friendly assets. Active air defense measures include the use of aircraft and surface-to-air missiles (SAMs). Passive defenses, on the other hand, are nonlethal measures that minimize the effectiveness of an air attack. Deception, dispersion, and hardening are passive defense examples.⁹⁰

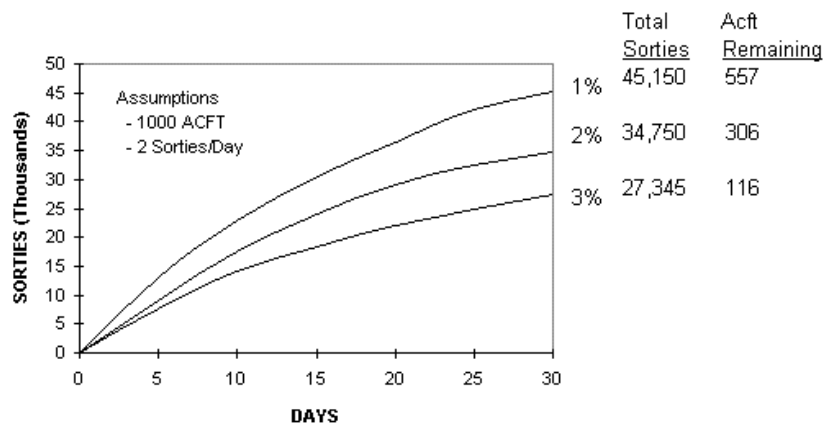
Since SEAD is the neutralization and destruction of enemy surface based air defenses, this section analyzes the surface element of an air defense system. A robust air

defense system combines both air and surface defense elements, but this study focuses on the systems that enable surface-based weapons to engage targets.

This section summarizes air defense systems' roles and organization and offers a system level analysis of critical functions. A basic description of the functions and elements inherent in air defense systems offers the reader an understanding of the necessary tasks for successful target engagement. Then, a discussion of air defense control provides insight on how control methodology changes effectiveness and vulnerability. Finally, an analysis of surface-based defense systems highlights the potential impact of targeted subsystems on mission performance. A key element to the analysis will be the linkages of diverse elements in the system and the crucial roles that interconnections play.⁹¹ Real world defenses generally combine elements of the three control methods. Three notional air defense systems, centralized, semi-autonomous, and autonomous are used to span the concept. Abstract analysis of these systems provides the building blocks for the higher level analysis necessary for actual defenses. The nature of air defenses, whether SAM or AAA dependent, mobile or fixed, centralized or autonomous, and concentrated or dispersed, has significant impact on the development of air strategy. Understanding their nature is crucial to the gaining of air superiority.

Surface-Based Defense Concepts

The primary function of surface-based defense is to provide protection to forces and critical assets. Attriting enemy air vehicles is the primary mechanism for providing this protection. Attrition occurs by two means, physical and virtual attrition. Physical attrition, the actual destruction of attacking air vehicles, is the main purpose of an effective defense system. Figure 1 shows the impact of attrition rates on a force of 1000 aircraft flying 2 sorties per day over a 30 day period.⁹² Clearly, attrition rates of merely 1% (considered very good during W.W.II) still accumulate significant combat losses with a 30 day cumulative loss of 44%. Acceptable attrition rates depend on war objectives and national will, but today, few air forces could sustain 1 percent attrition.⁹³



Source: Col Richard Atchison, "Electronic Combat," *Journal of Electronic Defense*, April 1987.

Figure 1. Theoretical Attrition Rates Over 30 Days

In addition to actual losses, air defenses cause virtual attrition. Virtual attrition is the opportunity cost of providing force protection for offensive operations. It degrades offensive firepower by increasing the need for suppression or decreasing weapon accuracy due to standoff requirements. The greater the depth of the defenses, the higher the cost of suppression in offensive firepower lost. Aircraft weapon stations that could hold offensive ordinance must carry defensive pods and missiles for self-protection.⁹⁴ In addition, bombing accuracy decreases due to the increased errors caused from bombing above AAA and manportable (MANPAD) range.⁹⁵ Attackers must carry increased loads to achieve the same outcome, causing a virtual attrition of combat effectiveness.

Physical and virtual attrition influence the attacker's cost-benefit calculus.⁹⁶ Although surface defenses have never gained and maintained air superiority singularly, they can have a powerful effect on the attacker's combat effectiveness. The attacker's job is to optimize forces to provide an adequate balance between physical and virtual attrition. A high level of SEAD, may effectively suppress defenses, but may not allow the appropriate economy of force to affect enemy critical vulnerabilities. On the other hand, a low level of self-protection may result in unacceptable physical attrition even though high value targets are killed.

In addition to force protection, a secondary mission of air defense systems is to provide operations security (OPSEC). FM 44-100, *US Army Air Defense Operations*, provides guidance on operations for the security role:

Air defense contributes to counterreconnaissance by destroying UAVs and aircraft conducting reconnaissance, intelligence, surveillance, and target acquisition (RISTA) operations against the force. Frequent moves disrupt the enemy command and control cycle. These measures help commanders protect their force from enemy observation throughout the conduct of operations.⁹⁷

In effect, the a secondary function of air defense can be to “blind” the enemy by denying his surveillance, thus preserving the element of surprise.⁹⁸

Air Defense Processes

To perform its mission adequately, an air defense system must accomplish three major processes. First, it must be able to detect potential threats by finding and tracking them. Second, it must identify threats and provide control to sensors and weapons, linking weapon systems to detection systems. Finally, active defenses must engage and destroy threats with the weapons available, and report the results. The complexity of these processes depends on the type of air defense system, but all systems must accomplish these steps. Single weapon--single sensor, systems are less complex than multi-weapon--multi-sensor systems, but they still must detect, control, and engage.⁹⁹ Each of these air defense processes provides ample opportunity for SEAD exploitation.

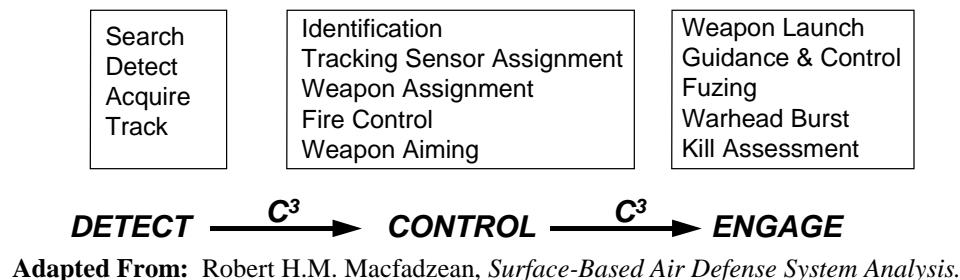


Figure 2. Air Defense Engagement Processes

The air defense processes of detect, control, and engage are further broken into tasks. Figure 2 shows the air defense tasks.

Discussion of the air defense tasks follows:

Detection Tasks. The detection process involves finding a potential threat and establishing an initial track so that the system can accomplish the control process.

Search. Searching is the process where a sensor inspects a given volume. A scanning search involves the sequential glimpsing of small portions of the search volume until it covers the entire volume. A continuous search focuses on the total search volume at all times. Typically, a continuous search volume is smaller than a scan search volume.¹⁰⁰

Detection. Detection results when an operator or computer system discerns a new return from an active or passive air defense sensor. Detection systems include early warning radar, shorter range target acquisition radar, passive emissions, infra-red search and track, optical, and acoustic systems. Limited detection resources cover probable enemy attack axes.¹⁰¹

Acquisition. Detection is a single event that provides limited information. Acquisition is the repeated detection of a new target during several scans or over several seconds on a continuous look. It allows the sensor system to make a decision that a new target has appeared.¹⁰²

Tracking. Tracking occurs when sufficient sensor information is available to determine aircraft heading and speed. Tracking generally begins outside the selected weapons range.¹⁰³

Control Tasks. Once a contact is declared hostile, and the decision is made to prepare for engagement, the system transitions from detection to engagement. Control tasks define the process linking detection and engagement.

Identification. Friend or foe status determination begins by comparing new tracks to all known tracks. Defenses use various identification procedures to determine track intent. Identification methods include identification of friend or foe (IFF) system interrogation, non-cooperative target recognition,¹⁰⁴ and visual recognition. Rules of engagement (ROE) describe the conditions under which air defense systems can engage targets.¹⁰⁵

Tracking Sensor Association. Fused or filtered plots from multiple sources typically provide better track data for weapon engagement and battle management. Sensors are paired to threats for precision tracking based on the threat's priority for engagement.¹⁰⁶

Weapon Association. Like sensor assignment, weapons are paired to targets based on the threat's engagement priority and the capability of available weapons. The assignment process becomes more critical with increasing number of weapons and threats because of overkill and underkill possibilities.¹⁰⁷

Fire Control and Weapon Aiming. Fire control is the process of aiming the weapon so that a projectile or missile will hit the target. Firing doctrine determines the method of weapon employment. Two typical doctrines are "shoot-look-shoot" and "shoot-shoot-look." Shoot-look-shoot conserves missiles by waiting for a kill assessment before re-engaging. Shoot-shoot-look, on the other hand, increases the cumulative probability of a kill by shooting two missiles before determining target kill status.¹⁰⁸

Engagement Tasks. Engagement's function is to inflict and assess damage on the threat air vehicle and close the loop by providing feedback to the air defense system.

Launch. Launch of a missile or projectile occurs after several criteria are met. For an effective launch, a weapon should have smooth target tracking, a valid fire control solution, a hostile target ID with the required degree of certainty, and an intercept range within the weapon's range.¹⁰⁹

Guidance and Control. Most radar guided SAMs use some type of off-board guidance and control.¹¹⁰ Command guided SAMs require that the threat target and the SAM be simultaneously tracked by a ground site while the SAM site passes steering signals over a data link to the missile. Semi-active homing missiles steer towards reflected radar energy. They require that the threat be illuminated from the surface during the entire flight. Long range systems often employ a combination of command guidance and semi-active homing.¹¹¹

Some weapons receive little to no external guidance and control information. Infra-red missiles steer towards target heat sources while newer generation radar missiles, the SA-10 and Patriot for instance, steer by track-via-missile. The engagement radar initially tracks the missile and target, providing the missile with mid-course corrections. Then, an active radar seeker on the missile gives it terminal homing commands.¹¹²

Fuzing and Detonation. Detonation occurs when a fuze detects the target and initiates the warhead. Contact fuzes initiate on contact with the target, while proximity fuzes use some type of timing or sensing mechanism to initiate detonation.¹¹³

Kill Assessment. Kill assessment is the process of determining if the fired weapon successfully damaged the target. Considering this assessment a kill or no kill is declared

after some time interval. The fundamental problem is to reach a conclusion, quickly and with little chance of error, that a kill occurred. A successful kill assessment closes the loop on the air defense process.¹¹⁴

Command, Control, and Communications (C³) Systems

Effective control of diverse systems requires the capability to collect, process, display, and communicate vast amounts of information while denying the enemy access to the same. C³ ties together the elements of the air defense system by providing the links between the detect, control, and engage processes. These systems expedite command and control functions through fast, reliable, flexible, and secure exchange of information throughout the system.¹¹⁵ A defense system needs to tie together its sensors and weapons to set priorities, assign weapons systems, conserve assets, and inflict the greatest attrition possible on the attacking force. To do this, its communications systems must have sufficient capacity, electronic countermeasures resistance, and flexibility to accommodate information exchange among levels of command, even when an intermediate level has been disabled.¹¹⁶

The air defense processes, and the C³ link that joins them together form the functional elements to be analyzed shortly.

Employment

Air defense weapons are employed to provide either point, or area protection. Most air defense systems provide a combination of these coverages depending on the objectives of the air defense commander.

Area. Area defenses are typically arranged using a “belt” concept to engage the attacker far from critical targets. Area coverage allows the defense to engage the attacker during ingress into and egress from the area of responsibility. The main advantage of an area defense is that it provides for early engagement of attacking aircraft. Unfortunately, if the belt is breached, the entire area becomes vulnerable.¹¹⁷

Point. Point, or cluster defenses, provide for engagements in critical terminal areas. Due to the immense cost of an area defense, many countries opt for clustered defenses. US and European nations have replaced full area coverage because they no longer have the assets to provide defense on this scale. Protection of specific vital areas replaces static lines of defense.¹¹⁸ Another advantage of point defenses is that the attacker is most susceptible in the target area. The major disadvantage of this employment is that the defender must act quickly to defend near critical targets.

The air defense commander will typically employ surface-based assets to provide some balance of area and point coverage.

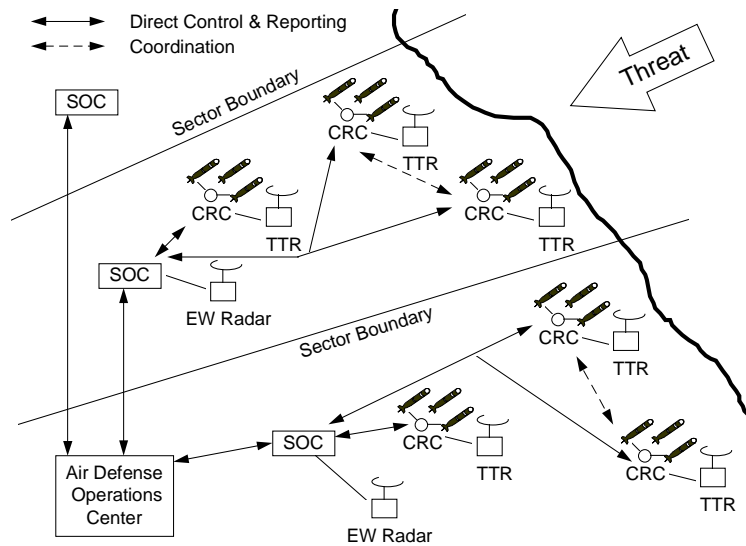
Methods of Control

To understand how C³ systems affect system behavior and effectiveness, one must understand the difference between command, control, and the systems that support them. Command is the authority to direct forces to accomplish a mission. For the air defense mission, unity of command is usually established in an area air defense commander (AADC). Control, on the other hand, is the ability to direct forces. Finally, communications, computers, and communications (C³) systems are means of providing command and control. Basically, command is a function, command and control a

process, and C³ a system to implement command and control.¹¹⁹ This analysis concentrates on control methods and their supporting C3 systems.

The type of command and control profoundly affects system operation. Centralized command and control typically is more efficient but also more vulnerable to system failure through manipulation of a critical node. A collection of autonomous systems, on the other hand, is fairly robust because each operates independently, but is less efficient at employing resources. The effectiveness of semi-autonomous and autonomous command systems depends on the quality of training and the organizational ability for lower echelon commanders to fill informational gaps with initiative.¹²⁰

Centralized. Most air defense systems typically employ centralized control for two reasons. First, centralized control allows unity of effort and helps ensure the most effective use of limited assets. Army FM 44-100 lists centralized control as one of the basic tenets of air defense. According to the manual, “Centralized control is essential to ensure integration and coordination of all air defense assets...to maximize their collective effect on the battlefield. Centralized control also facilitates the synchronization of offensive and defensive operations within the Army and among all the participants in joint or multinational operations.”¹²¹ Centralized control allows unity of effort allowing the defender to act across a wide spectrum, shielding critical assets with limited resources.¹²² It allows units to work together in depth, providing mutual support.¹²³ The second reason for centralized control is security. Dictatorial regimes favor centralized control to maintain a close hold on all sources of military power.¹²⁴



Adapted From: Group Captain M.B. Elsam, *Air Defence*.

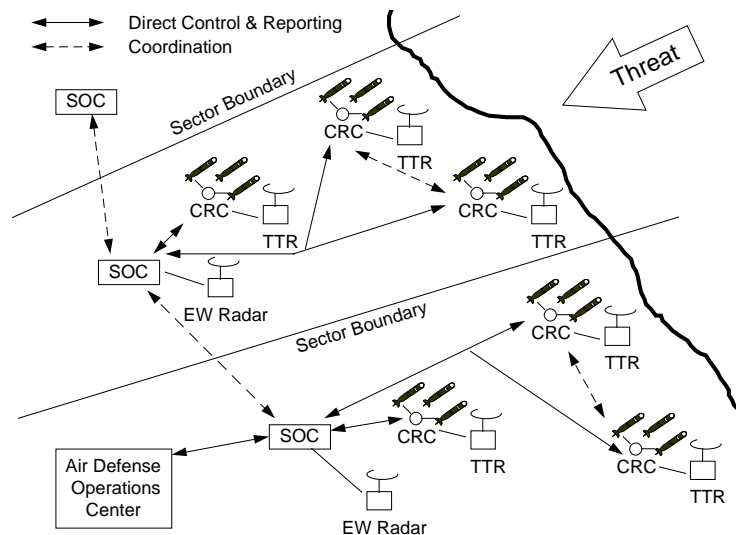
Figure 3. Centrally Controlled Air Defense System.

Typically, integrated air defense systems are hierarchical allowing centralized control of air defense assets. Figure 3 shows an example of a hierarchical air defense system. The air defense operations center (ADOC) forms an overall view of the air situation, makes threat prioritization, and allocates defense assets accordingly. A number of sector operations centers (SOCs), established geographically, coordinate early warning data, and allocate assets provided by the ADOC. Finally command and reporting centers (CRCs) detect and track intruders with target tracking radars (TTRs) and associated systems, assign individual weapons to targets, engage targets, and report results.¹²⁵ The net result is an integrated system that shares threat information and provides efficient control of the air battle.

The weakness of centralized systems is the potential for over-loading the decision making echelon resulting in failure of the overall air defense system. Without sufficient communications redundancy, or adequate flexibility in rules of engagement (ROE), lower level echelons can be isolated without sufficient information to perform their tasks.

Soviet-type systems, known for their centralized control, proved very vulnerable once isolated from the operations centers.¹²⁶ Each air defense regiment has the capability to operate autonomously but does not have sufficient equipment redundancy or sustainability to operate autonomously for more than short periods of time. Fire units separated from command and control exacerbates the danger of fratricide due to the lack of identification information.¹²⁷ Individual batteries become susceptible to coordinated air attack because of saturation and lack of early warning.¹²⁸

Semi-Autonomous.¹²⁹ Semi-autonomous control enables air defense assets to maximize their individual capabilities and meet the extreme air and missile threat engagement timelines. Higher echelons centrally task units, but flexibility allows lower echelon commanders determine how to implement orders.



Adapted From: Group Captain M.B. Elsam, *Air Defence*.

Figure 4. Semi-Autonomously Controlled Air Defense System

Figure 4 shows a notional semi-autonomous air defense control. The ADOC does not have direct control and reporting with all air defense command elements, but can still

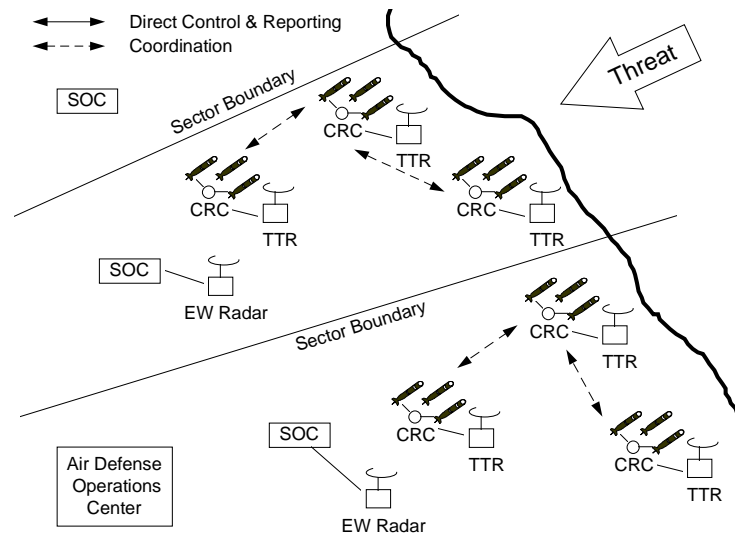
centrally task by using coordination routes between SOC's. Early warning and control and reporting information is still available through these sector coordination lines. Although the ADOC has lost direct control of some elements, it may maintain procedural control of lower echelons through rules-of-engagement (ROE).

Effective semi-autonomous systems require a higher level of hardware redundancy than centralized systems. Since ADOC fused detection and identification information may not be available, each sector should have a wider selection of these systems. Without additional indigenous capability, they become more susceptible to losing significant detection and control capability by losing a single system.

Establishing sound ROE and flexible communications systems allows effective semi-autonomous operations. Simple and unambiguous ROE provide a solid set of rules to follow in the heat of combat. ROE provide positive and procedural management directives that specify the circumstances in which engagement may take place. They enable the Area Air Defense Commander to retain control of the air battle, even without being in direct communications with lower echelons.¹³⁰ A robust and redundant communications network allows transfer of control in the event of a node, or sector, failure. For effective semi-autonomous operations the C² system should provide "graceful degradation" to allow making combat decisions at progressively lower levels.¹³¹ Adequate training with ROE, and alternate information paths, allows the semi-autonomous to become a most flexible and difficult system to target.

Autonomous. Autonomous operation occurs when individual air defense operators and elements operate without direction from higher authority. ROE usually procedurally controls autonomous operations, but the individual site solely performs threat detection

and engagement. ADOCs and SOC provide negligible positive control and information flow directly to the shooter. Numerous shooters may engage without coordination as targets emerge. Coordination between sites, if attempted, is a time consuming process due to a lack of C² automation.¹³² Autonomous systems, due to lack of integration with outside early warning and acquisition systems, may lack the ability to locate and track attacking aircraft effectively.¹³³ On the other hand, no single nodal degradation will cause significant degrade to a defense system composed of autonomous sites.



Adapted From: Group Captain M.B. Elsam, Air Defence.

Figure 5. Autonomously Controlled Air Defense System

Figure 5 depicts a notional autonomously controlled air defense system. Individual air defense elements engage threats without direct control from higher echelons. Several elements may establish coordination, but they lack integration with the entire system.

Air Defense Systems Analysis

The JFACC planning staff has a wide range of analysis resources available to plan the targeting and exploitation of enemy air defense systems. The National Air

Intelligence Center, among other agencies, provides analysis for air targeting of enemy systems. They analyze not only limited hardware performance, but the human processes within a system. Their effort provides insight into the dynamic nature of country C² processes and their influence on military effectiveness.¹³⁴ The bulk of this analysis is classified and not available for general discussion. This study provides risk analysis, as presented by Maj Steven M. Rinaldi in *Beyond the Industrial Web: Economic Synergies and Targeting Methodologies*, and Charles Perrow, as quoted in “Command and Control at the Crossroads,” as a tool for performing a rough analysis on air defense systems.¹³⁵ This analysis attempts to consider the system as a whole, while recognizing subsystem dependencies.

Risk analysis seeks to explain how subsystems interdependence affect macro system operation. The analyst determines system characteristics by classifying subsystems' links and dependencies. The linkages between major subsystems or processes rank from tight to loose. Tightly coupled linkages refer to elements that are strongly dependent on one another. Disturbances tend to propagate through a tightly coupled system. Time-dependent processes typify tightly coupled systems. Loose coupling, on the other hand, implies relatively independent elements. Short term disturbances of loosely coupled elements have a minor impact on overall system performance.¹³⁶ This study subjectively evaluated air defense subsystems using four criteria: time dependency, redundancy, hardiness, and criticality. Tightly coupled elements perform time critical processes, lack redundancy and hardiness, and are critical to macro system performance. The purpose of dynamic analysis, for the planner, is to determine subsystems that have tight couplings, promising system wide disturbances.

This study examined three notional defense systems based on the control concepts of centralized, semi-autonomous, and autonomous control. Since the control method links detection, control, and engagement tasks, the analysis assumes that as systems move from centralized to autonomous, task performance moves from the higher echelons (ADOCs) to the lower echelons (CRCs and batteries). For instance, an autonomous system CRC must provide for its own detection, identification, and engagement decisions, while in a centralized system these functions are performed at higher echelons. Most air defense systems combine these control methods depending on the phase and nature of a conflict.

Centrally Controlled Air Defense System.

Analysis of centrally controlled air defenses determined subsystem linkages indexed by the air defense processes. Table 1 displays the coupling of subsystems to overall defense system performance.¹³⁷ The evaluation assumed that high level command echelons, ADOCs and SOCs, allocate information and weapons according to threat priority allowing efficient management of the defense. The ability of the system to operate without its normal centralized control depends on the training and quality of the personnel that operate the system, and the flexibility of the ROE to allow initiative at lower levels.

Table 1. Centralized Air Defense Process Linkages

Air Defense Element and Associated Functions	Location	Coupling to System Performance
Detection <ul style="list-style-type: none"> • Ground Early Warning Radar • Airborne Early Warning Radar • Passive Detection • Infra-Red Search and Track • Target Tracking Radar • Optical Systems • Visual Track 	ADOC/SOC ADOC/SOC ALL SOC/CRC CRC/BTY CRC/BTY BTY	Loose Loose Loose Loose Loose Loose Loose
Control <ul style="list-style-type: none"> • Identification Friend or Foe (IFF) • Non-Cooperative Target Recognition (NCTR) • Visual ID • Fire Control • ROE • Personnel 	ALL CRC/BTY BTY ADOC ADOC ALL	Tight Loose Loose Tight Loose Tight
Engage <ul style="list-style-type: none"> • Missile Launch/Gun Fire • Command Guidance • Independent Seeker Performance • Fuzing • Kill Reporting 	BTY BTY BTY BTY CRC/BTY	Loose Loose Loose Loose Loose
Command and Control Communications <ul style="list-style-type: none"> • Air Defense Operating Center • Sector Operating Center • Command and Reporting Center • Command and Control Network • Battery Network 	ADOC SOC CRC ALL BTY	Tight Tight Tight Tight Loose

The main area of interest in targeting a centralized air defense system is command and control, and the communication systems that support it. The C³ tasks are tightly coupled, because their time dependency and overall system requirement. Defense performance suffers without information normally provided by the command and control net. With the control system intact, coordination between operations centers allows engagement prioritization for maximum effect. Degrading C³ increases time for individual batteries to detect and engage, allowing the attacker a window for exploitation. With highly centralized control, C³ degradation can deny early warning information to

SOCs and CRCs, allowing radar gap exploitation for the attacker while increasing fratricide probability for the defender.¹³⁸ Field air defense units then become susceptible to isolation and exploitation. In many cases, procedural controls and rules of engagement (ROE) inhibit weapons designed to operate autonomously from doing so.¹³⁹ Additionally, former Soviet Union fire control units traditionally rely on higher echelon processed information about targets, making fire control tightly linked to C³.¹⁴⁰

Other elements of the air defense system show tight coupling. For instance, the effectiveness of the system relies on adequate identification friend-or-foe procedures to sort friendly from threat aircraft. Degradation to IFF capability can insert a large amount of ambiguity into identification performance, slowing the detect-control-engage cycle. Personnel are essential to system operation. Highly trained, motivated personnel provide a significant measure of effectiveness. Attempts to demoralize personnel, especially at the ADOC and SOC level can significantly degrade performance.

However, many elements of the centralized system show loose coupling since redundancy or shifting of resources can compensate for system degradation. Detection subsystems loosely couple since the centralization of information allows redundancy in early warning capability. Other radars can compensate for the loss of a single ground early warning radar. Early warning information can be determined by fusing numerous acquisition and target tracking systems. Overall a centralized system offers the flexibility to compensate for the loss of any single detection system. No single detection system loss is likely to degrade the system severely. Engage functions are also loosely coupled. These functions, performed at the battery level, provide only minimal degradation to the

macro system. Therefore attackers should limit attempts at affecting individual sites, unless this would create opportunity to exploit higher payoff systems.

ROE couples loosely in a centralized system since the senior command element, by definition, has positive control over information and engagement decisions. However, if the system is overloaded or driven to semi-autonomous control, ROE has significant impact on system operation. Unfortunately, people that train with the expectation of positive control from above may not function well under semi-autonomous control even if the ROE provides for it.

Campaign SEAD on higher order command and control (ADOCs and SOC), and communications offers the greatest prospect for a synergistic degrade of an IADS. Although loosely coupled, a massive attack on early warning can significantly degrade detection capability. A SEAD operation modeled after operations in the Gulf can cause system collapse allowing only pockets of resistance. If successful, the C^3 attack drives the system towards autonomous operations. As the system operates more autonomously, lower echelon C^2 becomes a valuable target.

Semi-Autonomously Controlled Air Defense System

Table 2. Semi-Autonomous Air Defense Process Linkages

Air Defense Element and Associated Functions	Location	Coupling to System Performance
Detection <ul style="list-style-type: none"> • Ground Early Warning Radar • Airborne Early Warning Radar • Passive Detection • Infra-Red Search and Track • Target Tracking Radar • Optical Systems • Visual Track 	ADOC/SOC ADOC/SOC ALL SOC/CRC CRC/BTY CRC/BTY BTY	Tight Tight Tight Tight Tight Loose Loose
Control <ul style="list-style-type: none"> • Identification Friend or Foe (IFF) • Non-Cooperative Target Recognition (NCTR) • Visual ID • Fire Control • ROE • Personnel 	ALL CRC/BTY BTY SOC ADOC ALL	Tight Tight Loose Tight Tight Tight
Engage <ul style="list-style-type: none"> • Missile Launch/Gun Fire • Command Guidance • Independent Seeker Performance • Fuzing • Kill Reporting 	BTY BTY BTY BTY CRC/BTY	Loose Loose Loose Loose Tight
Command and Control Communications <ul style="list-style-type: none"> • Air Defense Operating Center • Sector Operating Center • Command and Reporting Center • Command and Control Network • Battery Network 	ADOC SOC CRC ALL BTY	Loose Tight Tight Tight Tight

The system interactions change for a semi-autonomous defense due to the different control and information paths used. The evaluation of the system assumes that the SOC controls the air battle and information flow with less integration and fusion of information by the ADOC. Table 2 shows the subsystem coupling for a semi-autonomous defense.

Detection systems grow in importance as air defense moves towards semi-autonomous control. Local air defense commanders are less likely to have a picture of the entire air battle because lower echelons control information gathering. SOC's require more indigenous long range detection capability to compensate for lack of fused "big picture" information from the ADOC. Without the "big picture," engagements become more time critical events. Early detection increases time availability since the correlated battle picture is not available from above. Early detection systems at the SOC level are less likely to be redundant,¹⁴¹ making detection information more critical due to less alternate information paths.

Control tasks become more tightly coupled because the time for adequate identification and weapon allocation compresses. Less time is available to lower echelon commanders to detect and control the engagement before the target is in weapon employment range. Kill reporting becomes more critical as information redundancy decreases. ROE also becomes more critical because it becomes a primary method for the area air defense commander to control the air battle by prescribing approved engagement conditions.¹⁴² Along with time compression, the semi-autonomous system will likely have less redundancy for identification and will have to rely more on procedural identification measures.

The focus of C³ targeting moves down from the ADOC to sector control. Properly trained semi-autonomous units should suffer little degradation with the removal of the ADOC. Degrading sector communications, on the other hand, should degrade sector performance. In the same light, the removal of a SOC will have a significant

impact on systems performance, because CRCs and below would be forced to rely on their indigenous detect and control capability..

Engagement tasks still loosely couple to system performance, since any attempt to affect local, CRC or below, tasks will likely have only a small impact on overall system performance. For the same reason, short range tracking systems show loose coupling to overall system ability.

Autonomously Controlled Air Defense System

Table 3. Autonomous Air Defense Process Linkages

Air Defense Element and Associated Functions	Location	Coupling to System Performance
Detection <ul style="list-style-type: none"> • Ground Early Warning Radar • Airborne Early Warning Radar • Passive Detection • Infra-Red Search and Track • Target Tracking Radar • Optical Systems • Visual Track 	ADOC/SOC ADOC/SOC ALL CRC/BTY CRC/BTY CRC/BTY BTY	Loose Loose Loose Tight Tight Tight Tight
Control <ul style="list-style-type: none"> • Identification Friend or Foe (IFF) • Non-Cooperative Target Recognition (NCTR) • Visual ID • Fire Control • ROE • Personnel 	ALL CRC/BTY BTY CRC/BTY ADOC ALL	Tight Tight Tight Tight Tight Tight
Engage <ul style="list-style-type: none"> • Missile Launch/Gun Fire • Command Guidance • Independent Seeker Performance • Fuzing • Kill Reporting 	BTY BTY BTY BTY CRC/BTY	Loose Loose Loose Loose Tight
Command and Control Communications <ul style="list-style-type: none"> • Air Defense Operating Center • Sector Operating Center • Command and Reporting Center • Command and Control Network • Battery Network 	ADOC SOC CRC ALL BTY	Loose Loose Loose Loose Tight

The autonomous air defense system evaluation assumes that control of the engagement occurs at the CRC or below. This does not discount the fact that the air

defense commander can have procedural control through ROE, but that he has no positive control over the weapons. Threat engagement decisions and information flow occurs at the lowest command levels with few inputs from supporting units.

In the autonomously controlled defense, the individual battery performance determines the effectiveness of the system. Control and engagement tasks become more important, because autonomous systems rely on no external source of detection or identification information.¹⁴³ With little mutual support available, battery success and survival depends on the strength of the each engagement. Likewise, to defeat the system, the attacker must beat the system in one-on-one engagements. The engagement subsystems such as command and guidance, seeker performance, and fuzing affect the macro system performance. Degrading higher echelon command and control does little to degrade system performance since they are already separated procedurally. The battery depends on multi-role acquisition and tracking systems to cue weapon systems for engagement.¹⁴⁴ The major disadvantage to the defense is that these warning systems do not usually provide long range coverage, therefore engagement timelines are further compressed. Additionally, these systems lack redundancy and hardiness at the battery level. One attack on a multi-role radar can render a site ineffective.

C³ is loosely coupled to system performance due to its independence from higher command elements. More important areas of C³ operation are information paths from the CRCs to the firing batteries. On the other hand, ROE critically determines system performance by procedurally tying it to higher command. An advantage of this system is that, if trained properly, its effectiveness does not diminish by removing higher levels of command. ROE and training determine system effectiveness.

Traditionally, the goal of campaign SEAD is to force air defense systems down to autonomous control allowing them to be more easily targeted. Once down, this is a weaker system than one that was designed to be autonomous. One word of caution to the planner, however, is that degrading poorly functioning centrally controlled systems can actually improve system performance by freeing the initiative of subordinate commanders.¹⁴⁵

Summary

The function of an air defense system is provide force protection by engaging and destroying air threats. To perform this function the system must be able to detect, control, and engage targets with fielded weapons. Command and control communications ties the detection functions to the engagement elements for effective target engagement. Any decrease in the probability of performing any of the air defense elements decreases the probability of a successful intercept. Air defense systems employ either centralized, semi-autonomous, or autonomous control over their forces. Centralized systems are more able to detect and target intruders efficiently, but are more susceptible to disruption through attacks on command and control networks. Autonomous systems are generally less efficient, particularly if they are trained as centralized systems and degraded to autonomous operation. Generically, though, autonomous operations suffer less performance degrades when severed from communications.

This study evaluated three control methods using dynamic analysis to show the linkage between air defense elements and overall system performance. Table 4 is a summary of the subsystem interactions.

Table 4. Summary of Air Defense Subsystem Interactions

Air Defense Element and Associated Functions	Coupling to System Performance		
	Centralized	Semi-Autonomous	Autonomous
Detection <ul style="list-style-type: none"> • Ground Early Warning Radar • Airborne Early Warning Radar • Passive Detection • Infra-Red Search and Track • Target Tracking Radar • Optical Systems • Visual Track 	Loose Loose Loose Loose Loose Loose Loose	Tight Tight Tight Tight Tight Loose Loose	Loose Loose Loose Tight Tight Tight Tight
Control <ul style="list-style-type: none"> • Identification Friend or Foe (IFF) • Non-Cooperative Target Recognition • Visual ID • Fire Control • ROE • Personnel 	Tight Loose Loose Tight Loose Tight	Tight Tight Loose Tight Tight Tight	Tight Tight Tight Tight Tight Tight
Engage <ul style="list-style-type: none"> • Missile Launch/Gun Fire • Command Guidance • Independent Seeker Performance • Fuzing • Kill Reporting 	Loose Loose Loose Loose Loose	Loose Loose Loose Loose Tight	Loose Loose Loose Loose Tight
Command and Control Communications <ul style="list-style-type: none"> • Air Defense Operating Center • Sector Operating Center • Command and Reporting Center • Command and Control Network • Battery Network 	Tight Tight Tight Tight Loose	Loose Tight Tight Tight Tight	Loose Loose Loose Loose Tight

Important for the air planner to note is the coupling changes that occur depending on the amount of centralized control inherent.

Future Trends

Future air defense systems will try to “loosen” critical processes by countering vulnerabilities with increased redundancy and hardiness. One area promising rich reward is distributing communications to allow centralized control through decentralized communications links.¹⁴⁶ Disrupting communications will become more difficult as systems become more redundant and disperse. Distributed networks, like the internet, will allow centralized control without the danger of being disabled through a critical node. The loss of a single node will cause only minor system degradation. Instead of addressing information through a central distribution system, the network passes messages by numerous routes making it less vulnerable to a well-placed precision munition.¹⁴⁷ Globally broadcast data will allow each user to sort for desired data providing a fully integrated air picture to users of all levels.¹⁴⁸ Although more difficult to target, large targeting payoffs can occur by disabling the network server. Total system collapse can occur¹⁴⁹ A centrally controlled defense system still remains extremely vulnerable as long as its control path can be disabled.

Another area for improvement is the hardening of critical command and control systems. Potential adversaries are expected to improve hardening of critical operations centers to decrease vulnerability to air attack. The swiftness and accuracy of Coalition air attacks in the Gulf, showed the vulnerability of exposed command centers.

Finally, potential adversaries are unlikely to allow stealth to go undetected. Improving stealth detection capability can negate the U.S.’s current detection advantage. Several methods are already available to detect stealth platforms. Bi-static radar will allow the radar detection of low observable platforms by intercepting deflected energy

from them. Additionally long wave IR detection systems are in development to detect aircraft skin temperature.

Defenses will continue to react to the attacker's technological providing an adaptive protection system to critical assets.

Notes

⁸⁸ **critical node**--An element, position, or communications entity whose disruption or destruction immediately degrades the ability of a force to command, control, or effectively conduct combat operations. Joint Pub 1-02, *Department of Defense Dictionary of Military and Associated Terms*, 23 March 94.

⁸⁹ Joint Pub 3-01.4, *Joint Tactics, Techniques, and Procedures (JTTP) for Joint Suppression of Enemy Air Defenses*, 25 July 1995, I-3.

⁹⁰ AFDD 10, *Counterair Operations*, Final Draft, 1 September 1996, 5-6.

⁹¹ Numerous analysis techniques are available to determine critical nodes and vulnerabilities. Dynamic analysis as presented by Steven M. Rinaldi, *Beyond the Industrial Web: Economic Synergies and Targeting Methodologies*, (Maxwell AFB AL: Thesis, School of Advanced Airpower Studies, 1994) provides a tool for establishing a holistic approach to targeting by recognizing the adaptive nature of systems. Key to dynamic analysis is establishing the degree of coupling that a broken link has throughout a system.

⁹² Col Richard M. Atchison, USAF, "Electronic Combat," *Journal of Electronic Defense* 10, no. 4 (April 1987), 60-64

⁹³ Although U.S. attrition rates were historically below 1% since World War II, the Israelis suffered 5 percent attrition to surface defenses in the opening phases of the Yom Kippur War.

⁹⁴ Norman Friedman, *Desert Victory: The War for Kuwait*, (Annapolis: Naval Institute Press, 1991), 151.

⁹⁵ Medium and high-altitude bombing reduced the effectiveness of non precision attacks in Desert Storm. F-16 circular error probable went from 30 feet to 200 feet in some cases. James A. Winnefeld, Preston Niblack, and Dana J. Johnson, *A League of Airmen: U.S. Air Power in the Gulf War*, (Santa Monica, CA: RAND Corporation, 1994), 127-128. Soviet bombing accuracy in Afghanistan was reduced by Mujahideen Stinger operations. David Isby, "Soviet Surface-to-Air Missile Countermeasures," *Jane's Soviet Intelligence Review* 1, no. 1 (January 1989), 44.

⁹⁶ Major General W. Thomas West, "Air Defence in Support of Contingency Operations," *RUSI Journal* 139, no. 5 (October 1994), 58.

⁹⁷ FM 44-100, *US Army Air Defense Operations*, 15 June 1995, n.p., on-line, Internet, 20 March 1997, [http://www.atsc-army.org/cgi-win/\\$atdl.exe/fm/44-100/fm44100.htm](http://www.atsc-army.org/cgi-win/$atdl.exe/fm/44-100/fm44100.htm)

⁹⁸ Lt Col Frank Caravella, "Division Air Defense Study: A Bridge to the Future," *Air Defense Artillery*, January-February 1994, 2.

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⁹⁹ Robert H. M. Macfadzean, *Surface-Based Air Defense System Analysis*, (Boston, MA: Artech House, 1992), 39. Air Vice-Marshal A. J. C. Bagnall, "The United Kingdom's Air Defence Forces," *RUSI Journal* 139, no. 5 (October 1994), 45.

¹⁰⁰ Macfadzean, 39-40.

¹⁰¹ Frank Heilenday, *Principles of Air Defense And Air Vehicle Penetration*, (Washington D.C.: CEEPress Books, George Washington University, 1988) 1-1. Dunnigan, 194. An important aspect of the Intelligence Preparation of the Battlefield (IPB) is to analyze attacker likely threats and avenues of approach to ensure that limited air defense assets provide force protection IAW the commander's intent. Lt Gen John E. Miller, "Protecting the Force: An Air Assault Division Perspective," *Air Defense Artillery*, November-December 1993, 19. In addition, a coordinated plan of friendly ingress routes allows defenders to separate friendly aircraft from attackers. Maj Mike McAllister, "A2C2 Information: The 25th Infantry Division Technique," *Air Defense Artillery*, July-August 1996, 16-18.

¹⁰² Macfadzean, 43.

¹⁰³ Ibid., 46-47.

¹⁰⁴ Jet Engine Modulation (JEM) radar identification provides high quality target identification for some systems. Mark Hewish, "Low-Level Air Defense: New Sensors Enhance Effectiveness," *International Defense Review* 27, no. 6 (June 1994), 47.

¹⁰⁵ Macfadzean, 47-48.

¹⁰⁶ Heilenday, 1-1. Dunnigan, 195. A. J. Wilson, "Technical Challenges and Opportunities for Future Air Defense," *RUSI Journal* 139, no. 5 (October 1994), 68. Macfadzean, 49-50.

¹⁰⁷ Macfadzean, 49.

¹⁰⁸ Ibid., 334. Col Allen M. McDavid, and Capt Brian E. Bosworth, "Cruise Missiles: Tomorrow's Threat on Sale Today," *Air Defense Artillery*, May-June 1996, 3-4.

¹⁰⁹ Macfadzean, 58.

¹¹⁰ Although newer missiles use track-via-missile, they are just starting to become proliferated. Most defenses still use older generation systems.

¹¹¹ Group Captain M. B. Elsam, *Air Defence*, (London: Brassey's Airpower, Vol. 7, 1989), 59-61.

¹¹² Steven J. Zaloga, *Soviet Air Defense Missiles: Design, Development, and Tactics*, (Surrey, England: Jane's Information Group, 1989), 112. Tony Cullen and Christopher Foss, eds., *Jane's Land-Based Air Defense*, (Surrey, England: Jane's Information Group, 1995), 300-305.

¹¹³ Macfadzean, 61.

¹¹⁴ Ibid., 62.

¹¹⁵ AFDD 10, 7.

¹¹⁶ FM 44-100, *US Army Air Defense Operations*, 15 June 1995, n.p., on-line, Internet.

¹¹⁷ Elsam, 57-58. Macfadzean, 321.

¹¹⁸ Air Commodore Peter Millar, "Air Defense of the Central Region," *RUSI Journal* 139, no. 5 (October 1994), 51-53. Macfadzean, 321.

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¹¹⁹ Col Maris McCrabb, "A Normative Theory Of Air And Space Power Command And Control," Draft; on-line, Internet, 22 May 1997, available from http://www.au.af.mil/au/saas/theory/mccrb_c2.doc.

¹²⁰ Martin van Creveld, *Command in War*, (Cambridge, MA: Harvard University Press, 1985), 271

¹²¹ Although centralized control is also a master tenet for airpower employment, the Army definition is used here since it specifically addresses the employment of surface-based defenses. FM 44-100, *US Army Air Defense Operations*, 15 June 1995, n.p., on-line, Internet.

¹²² West, 59.

¹²³ Friedman, 149.

¹²⁴ Joint Pub 3-01.4, I-5.

¹²⁵ Wilson, 65.

¹²⁶ The destruction of Iraqi control centers opened them to large scale attack. They were never able to integrate early warning to weapon employment systems. The Iraqi defense was fragmented within the first hours of attack. Friedman, 151-152.

¹²⁷ Zaloga, 189-190.

¹²⁸ The Iraqi centralized air defense system was basically ineffective strategically within hours of combat operations. Coalition forces successfully separated firing batteries from sector operations centers drastically reducing Iraqi ability to coordinate and conduct an adequate air defense. *Conduct of the Persian Gulf War*, Final Report to Congress, (Washington D.C.: Department of Defense, April 1992), 154.

¹²⁹ Semi-autonomous command is analogous to the Air Force/Army tenet of centralized control with decentralized execution. Centralized control allows unity of effort and targeting synergies, while decentralized execution improves responsiveness and flexibility. The term semi-autonomous is used to be consistent with Multi-Command Manual 3-1 control references.

¹³⁰ FM 44-100, *US Army Air Defense Operations*, 15 June 1995, n.p., on-line, Internet.

¹³¹ Group Captain M. B. Elsam, *Air Defence*, (London: Brassey's Airpower, Vol. 7, 1989), 73-74.

¹³² Lt Col James R. Brungress, *Setting the Context: Suppression of Enemy Air Defenses and Joint Warfighting in an Uncertain World*, (Maxwell AFB, AL: Air University Press, 1994), 166.

¹³³ *Conduct of the Persian Gulf War*, 120.

¹³⁴ James H. Homer, NAIC Foreign C3 Process Analyst, Briefing Notes, "National C2 Branch, TACN," 12 Mar 97.

¹³⁵ Thomas J. Czerwinski, "Command and Control at the Crossroads," *Parameters* 26, no. 3 (Autumn 1996), 129-130.

¹³⁶ Rinaldi, 7-9.

¹³⁷ Data compiled from the following sources: Tony Cullen, and Christopher Foss, eds., *Jane's Land-Based Air Defence*, (Surrey, England: Jane's Information Group, Ltd., 1995); Peter Rackham, ed. *Jane's C4I Systems*, (Surrey, England: Jane's Information Group, Ltd., 1995); Steven J. Zaloga, *Soviet Air Defense Missiles: Design, Development,*

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and Tactics, (Surrey, England: Jane's Information Group, 1989); Lee, R.G., et al., *Guided Weapons*, Land Warfare: Brassey's New Battlefield Weapons Systems & Technology Series, Volume 1, (London: Brassey's Defence Publishers, 1988); *The International Countermeasures Handbook*, 15th ed., 1990, Defense Electronics (Englewood Colo.: Cardiff Publishing); Boyd, Joseph A., et. al., eds., *Electronic Countermeasures*, (Los Altos, CA: Peninsula Publishing, 1978); A. Sumin, "Russian Air Defence Forces," *Military Technology* 17, no. 7 (July 1993), 27-28; Trevor Nash, "The Changing Face of AD in the UK," *Military Technology* 17, no. 7 (July 1993), 24-26; Lt Col Dirk Engels, "German Army Air Defense," *Air Defense Artillery*, November-December 1994, 39-43; Lt Col Morton W. Burdick, "Air Defence Artillery in the British Army," *Air Defense Artillery*, March-April 1996, 21-28.

¹³⁸ Zaloga 185-190.

¹³⁹ Major General M. F. L. Shellard, "Missiles Are Our Colours Too: Review of the Development of Air Defense Artillery 1901 to the Present - Part II," *Army Quarterly and Defense Journal* 124, no. 3 (July 1994), 318.

¹⁴⁰ Hewish, 44.

¹⁴¹ Exercises at the National Training Center show a significant decrease in protection capability with the loss of early warning information. Forward air defense battalions are developing a 40 km early warning capability with the forward area air defense (FAAD) C3I system, but this is significantly short of the range provided by traditional early warning radar (100+ km). Maj Gen Wesley Clark, "Protecting the Force," *Air Defense Artillery*, January-February 1994, 25. "Army Morphs Air Defense Artillery," *Signal* 50, no. 5 (January 1996), 36-41.

¹⁴² FM 44-100, *US Army Air Defense Operations*, 15 June 1995, n.p., on-line, Internet.

¹⁴³ Ibid.

¹⁴⁴ The 37 US Army MPQ-64 radars will provide Stinger and Avenger Infra-Red SAM units with radar early warning and tracking with the added ability of identifying non-cooperative targets. The targeting of this radar significantly reduces cueing ability of MANPAD units. Hewish, 47. "Army Morphs Air Defense Artillery," 36-41.

¹⁴⁵ Targeters can actually improve the performance of several centrally controlled IADS by removing inefficient interim control levels. Planners should not always assume that autonomous operations are inferior to centralized operations. James H. Homer, Foreign C2 Process Analyst. National Air Intelligence Center, interviewed by author, 15 May 1997.

¹⁴⁶ Robert K. Ackerman, "Air Force Pilots Engage Tactical Data Targets," *Signal* 51, no. 3 (November 1996), 19-23.

¹⁴⁷ Eliot A. Cohen, "The Meaning and Future of Air Power," *Orbis* 39, no. 2 (Spring 1995), 196.

¹⁴⁸ Maj James Ivey, "From last defense to Forward Defense: FAAD C3I Will Change the Way We Employ FAAD Systems," *Air Defense Artillery*, July-August 1993, 9-13. Robert K. Ackerman, "Battlespace System Offers Data Anywhere, Anytime," *Signal* 51, no. 5 (January 1997), 26-29.

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¹⁴⁹ America Online overload of January 1997 is an excellent example of how information dependent subsystems can be ineffective when the main server is overloaded or removed. Over 2 million people were unable to gain timely internet access due to over-subscription to the service.

Chapter 4

SEAD Value Modeling

This study value-modeled the SEAD mission to quantify airpower force qualities inherent in an air superiority operation. The emphasis of the model is on SEAD, but that does not preclude its use in determining priorities for other airpower mission elements. This study's motivation for building and evaluating the SEAD model is to lend some insight into the mission's complexity, while complementing the commander's intuitive thinking.¹⁵⁰ The purpose of this analysis was to understand the value of knowledge in conducting SEAD operations through decision modeling.

Classic decision making theory, in Joint Pub 3-56.1, *Command and Control for Joint Air Operations*,¹⁵¹ and Air Force Doctrine Document 2, *Theater Air Warfare*,¹⁵² describes the process for turning national objectives into war objectives and strategy. This process describes the inclusion of national and commander values concerning the sequencing and securing of objectives. One decision modeling method currently used by air planners, "strategy-to-tasks," attempts to link these goals and objectives down to operational tasks. This methodology provides a framework for linking military tasks to their higher order objectives. In this manner, commanders and their staffs can trace the objective linked to a specific task. Unfortunately, strategy-to-tasks offers no insight into the intuitive tradeoffs used to determine the appropriate weight of effort to each task. It

basically provides an audit trail tracking asset allocation, but offers no guidance in making the allocation decision.¹⁵³ Value modeling, on the other hand, provides one method to quantify normally subjective relationships. The value model highlights the elementary factors that define the overarching objective.

This study chose value modeling to explore SEAD force qualities for two reasons. First, Air Force 2025 developed a detailed value model that specifically addresses the employment of air and space power. This model represents hundreds of hours of work by field grade officers of diverse backgrounds towards defining the tasks and subtasks necessary for airpower employment. Its comprehensive collection of utility curves provided an excellent framework for analyzing SEAD elements.¹⁵⁴ Second, value modeling is an established analytical tool for wargaming decision making qualities.¹⁵⁵ The operations research community highly rates Keeney's value focused thinking process for decision analysis, providing the theoretical basis for the technique.¹⁵⁶

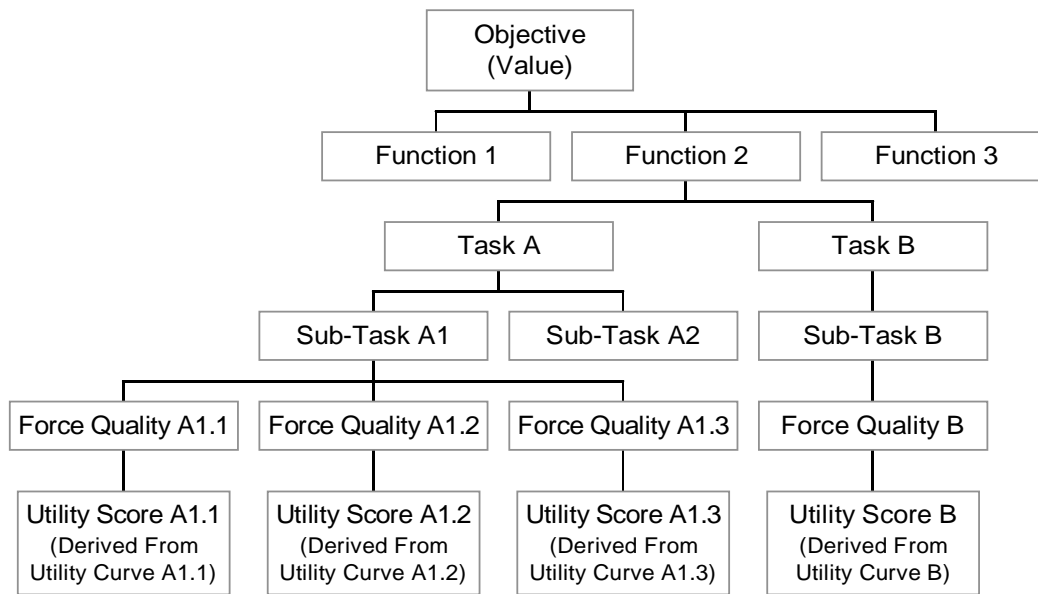
The purpose of this research is not to provide a plug and chug model for crisis action planning or to replace strategy-to-tasks as a planning tool. Rather it is to provide insight into how desired attributes for tasks change throughout a campaign, based on objectives and the nature of the threat. This research highlights the lessons captured while value modeling SEAD.

Value Modeling

When facing a complex situation, a model, or abstract mental framework, can lend insight into the complexity of the circumstances and lead to better informed decisions. To gain insight from such a model, it should focus on the basis for the

decision situation's complexity. This research uses a value model as a means to explore value choices through the identification and valuation of objectives.¹⁵⁷ Value modeling, or multi-attribute analysis, allows the weighing of preferences by decomposing them into their attributes, or qualities, and defining utility curves that describe the value of each attribute. The motivation of this analysis is to lend insight into complex situations complementing intuitive thinking.¹⁵⁸ Decision makers always incorporate values into decision situations, but value modeling explicitly highlights them by forcing the decision maker to quantify alternatives.

Essential to building a useful value model is establishing the situational objectives and their corresponding attributes. The first priority of the analyst is to identify a set of appropriate objectives. Then he must develop a structure combining the various objective attributes to reflect the decision maker's preferences. Simply listing desired objectives is inadequate, the model must reflect tradeoffs and alternatives between objectives. Value-modeling compels the decision maker, or staff, to determine not only what objectives are important, but quantifies how much improvement affects the objective. The value hierarchy, or value tree is a graphical representation of the decision-maker's values.



Source: Lt Col Jack A Jackson, Jr., et. al., “An operational analysis for Air Force 2025: An Application of Value Focused Thinking to Future Air and Space Capabilities.”

Figure 6. Notional Value Model

The value model is a hierarchical representation of objectives, functions, tasks, subtasks, force qualities and scoring functions. Figure 6 shows a notional value model. The value model, or value tree, is a branching structure with the most fundamental objective at the top. The lower level functions and tasks completely specify their higher level objective. Lower level categories must be mutually exclusive and completely exhaustive. In other words, the functions, tasks, and subtasks below the decision objective should represent it without repetition or duplication. The total collection of functions, tasks, subtasks, and force qualities should totally define the overall objective.

Objectives, Functions, Tasks, and Subtasks

Once establishing the overall objective, the analyst breaks it down into lower level functions, tasks, and subtasks. Therefore, the overarching objective is broken into functions. These functions are further broken into tasks and subtasks. The list of

functions, tasks, and subtasks should comprehensively define the top objective while at the same time being as mutually exclusive as possible.

Force Qualities

Force qualities define a desired attribute to achieve a subtask.¹⁵⁹ The force quality defines the measures of merit for an objective. Force quality attributes, to be useful, need to be measurable, operational, and understandable. Measurable means that the force quality can be quantitatively measured to describe the value judgment. Operational means that the attribute must describe the possible consequences with respect to the associated force quality. Finally, understandable requires each attribute to be unambiguous in describing consequences.¹⁶⁰ For example, a force quality of sensor coverage is measurable--its pattern of coverage is a function of field of view and time over interest area. It is operational because different levels of coverage provide different levels of sensor capability. Finally, it is understandable because the commander understands the consequences of varying levels of coverage.

Measures of Merit and Utility Curves

Each force quality measure of merit gauges system performance. Each measure of merit has a range of outcomes, from worst to best. The utility curve provides a quantitative value of each force quality's measure of merit.¹⁶¹

Utility functions provide a quantitative means for measuring the relative system performance for each measure of merit. In decision situations with uncertainties, the utility function is a utility curve describing the adequacy of the measure of merit.

Additionally, defining the curve shape and slope lends insight into the value of changing force quality performance.¹⁶²

Utility functions are the heart of the criteria tradeoff analysis. They give insight into the utility of a given measure of merit along with insight into the risk associated with improving the measure.¹⁶³ The horizontal axes of the utility curves are the measures of merit, while the vertical axes provides a quantitative value score. The horizontal axis may be a qualitative measure, but the vertical axis is a score of value typically ranging from 0 to 1, 0 to 10, or 0 to 100. Developing these functions is a significant analytical task, since analysts must discern value tradeoffs for the full range of a given measure of merit.¹⁶⁴

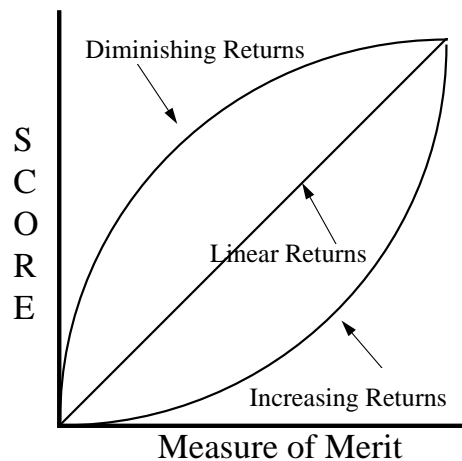


Figure 7. Increasing Utility Curves

Figure 7 shows a set of three curves whose utility increases with the measure of merit. The relationship between the measure of merit, and its corresponding value determines the shape of the curve. The most basic utility curve is the linear return curve shown in figure 7. The linear function implies that the decision maker values each incremental increase in performance just as much as the preceding increment. Another

curve is the diminishing returns curve. For this curve, each incremental increase in performance provides less value than the preceding increment. In other words, some system performance level is “good enough” and improvement above that level provides marginal returns. Finally, a utility curve may show increasing returns where each incremental increase in performance is valued more than the preceding one. In this case, the function must meet a threshold of performance before having substantive value.

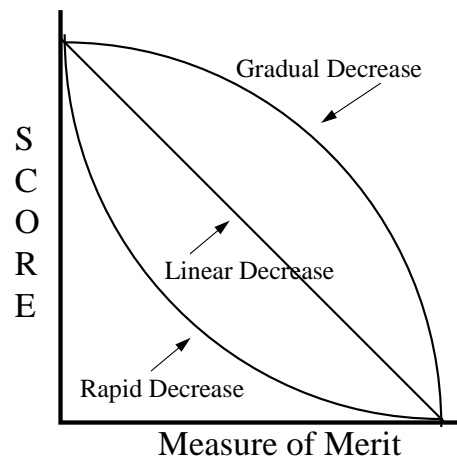
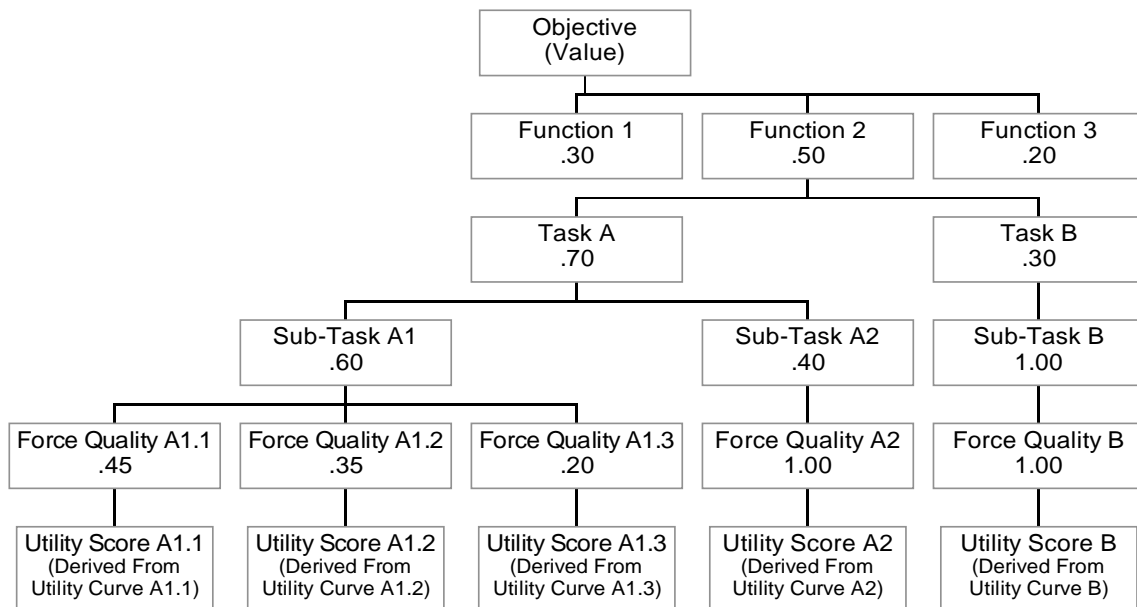


Figure 8. Decreasing Utility Curves

Utility curves can also show decreasing utility, or a combination of two or more curves. Figure 8 shows typical decreasing curves. The logic for these curves is similar to the increasing performance curves. Curve shape once again reflects decision maker value tradeoffs for criteria performance. Finally, another type of utility curve is the S-curve that combines two or more of the curves depicted above.

The decision maker, or area experts, define the shape and value of the utility curves for the given force quality in elicitation sessions. They place emphasis on putting numerical values on qualitative merits, and determining the shape and steepness of the curves. To sketch the curves, participants are asked to compare the utility of a force

quality for several measure of merit values. The participants generate the curve by comparing numerous value tradeoffs necessary for force quality performance. For instance they are asked to decide if doubling a criteria's performance doubles its utility, or does it change the value by some other increment. Through iteration of this process, a curve is developed.¹⁶⁵



Source: Lt Col Jack A Jackson, Jr., et. al., “An operational analysis for Air Force 2025: An Application of Value Focused Thinking to Future Air and Space Capabilities.”

Figure 9. Weighted Notional Value Model.

Weights

A fully developed value model is complex, requiring a great deal of legwork to flesh out meaningful measures of merit and utility curves. After the hierarchical structure of the value model is complete, the decision maker determines the relative importance of the functions, tasks, subtasks, force qualities, and measures of merit. The decision maker ranks the criteria at each level of the model to determining the relative importance of the criteria.¹⁶⁶ Figure 9 shows weights applied to the notional value model. Numerical

weights are assigned across each tier of the value model and the sum of each tier must equal one, implying that the sum of the sub-objectives totally defines the higher objective. By weighing sub-objectives and tasks the decision authority makes quality tradeoffs between these defining objectives. For instance, for function 2, the decision maker weighed task A's and task B's relative importance. By doing this, he places his value on these tasks. Prioritizing and weighing objectives throughout the model quantifies the stakeholder's choices. The objective weights change to reflect the decision maker's preferences for a given decision situation. Although impractical in a crisis situation, this tradeoff analysis gives the decision maker's staff insight into his logic of forming and weighing preferences.

Applying the Value Model

The value tree has many uses for the decision maker. The valued set of objectives is very effective at communicating information about the objective. It provides a common understanding of the tasks necessary to perform an objective and the relative importance of the tasks. It also provides a guide for data collection. The process of determining measures of merit for force qualities compels the decision maker into determining quantifiable measures for qualities. Value modeling breaks a complex function, which may not have a direct measure, into force qualities which are each measurable. Multi-attribute analysis also provides a basis for creating and evaluating alternatives to a decision situation. The weighted value tree with scoring functions provides the framework for evaluating alternatives.¹⁶⁷

Each alternative is forced through the value model from the bottom up. First, the analyst computes a utility score from the applicable utility curves. Each alternative is

assessed qualitatively over its measure of merit spectrum, and a utility score for each force quality is produced. If the utility score for that measure is zero then the force quality does not apply. Next, the analyst calculates weighted scores by multiplying the utility score by the product of all the branch weights, from the force quality to the highest level objective. An alternative's total score is the sum of all the weighted scores. The alternative with the highest score is the best choice for the decision situation.¹⁶⁸

The notional model in figure 9 is used to show function 2 branch scoring. Scoring proceeds from the bottom of the value tree to the top. To score the function 2 branch, a given alternative is initially scored for its utility on all force quality utility curves. This notional alternative produces the following utility scores for the force qualities A1.1, A1.2, A1.3, A2, and B: A1.1=37, A1.2=62, A1.3=18, A2=36, and B=83. The scale for utility scores is zero to 100. The resulting function 2 tree branch score is:

$$\begin{aligned}
 &= \{[(37)(0.45)(0.6)(0.7)(0.5) + (62)(0.35)(0.6)(0.7)(0.5) + \\
 &\quad (18)(0.2)(0.6)(0.7)(0.5)] + (36)(1.0)(0.40)(0.70)(0.50) + \\
 &\quad (83)(1.0)(1.0)(0.3)(0.5)\} \\
 &= 3.50 + 4.56 + 0.76 + 5.04 + 12.45 \\
 &= 26.31
 \end{aligned}$$

The analyst performs similar operations for every branch to score the alternative across the entire model. The value model quantitatively classifies qualitative alternatives through this scoring methodology. The highest scoring choice provides the most valued decision according to the scoring curves and decision maker weights.

For purposes of discussing SEAD, this study did not numerically score mission alternatives. Rather, it broke down a complex mission task into workable qualities and

measures of merit and analyzed a sampling of utility curves to gain insight into airpower's role in SEAD.

SEAD Value Model

To understand SEAD's role in airpower employment, one must determine its position within the overall airpower hierarchy. The Joint Force Commander, based on the Joint Force Air Component Commander's (JFACC) recommendation, will not only have to apportion SEAD assets, but he will have to assign priorities between close air support, interdiction, and strategic attack to name a few. This SEAD value analysis does not place undue importance on its role in gaining air control, but rather breaks the complexity of SEAD into finite elements for discussing element tradeoffs in performing its mission accomplishment. The intent is to illuminate the essence of SEAD and lessons for the strategist in terms of the elements and functions discussed.

SEAD is a portion of the aerospace control role of Air Force doctrine. Other airpower roles include force application, force enhancement, and force support. The roles are not mutually exclusive and significant overlap between roles exists. For instance the force enhancement mission of electronic combat is critical to the effective application of SEAD.

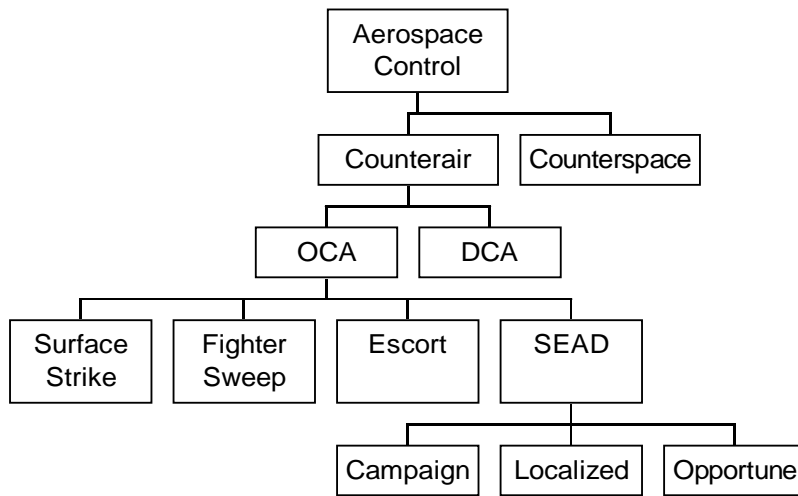
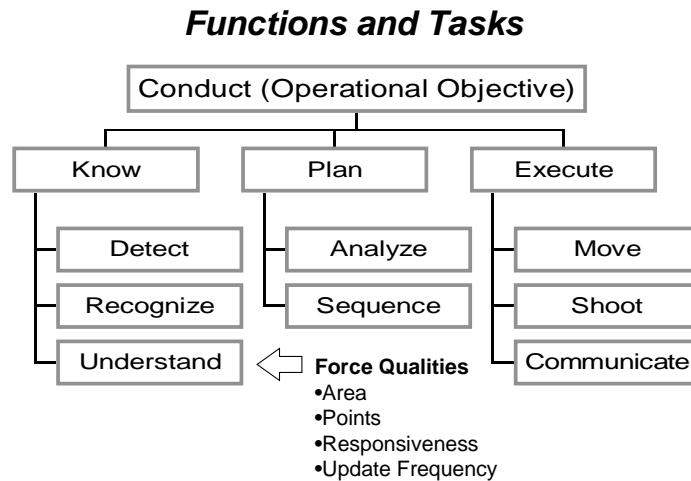


Figure 10. Aerospace Control Missions.

The SEAD value model flows logically from the Air Force's aerospace control role. Figure 10 shows the role of SEAD in the aerospace control role. According to AFM 1-1, aerospace control is normally the commander's first priority since it permits air and surface forces to operate more effectively while denying advantage to the enemy.¹⁶⁹ It provides freedom from attack and freedom to attack. As evident in Europe during World War II, and the Sinai in 1973, surface efforts gain effectiveness as aerospace control increases.

SEAD is one of the four missions comprising offensive counterair. Offensive counterair (OCA) consists of offensive operations aimed at destroying, disrupting, or limiting enemy air and missile threats. SEAD is one of the primary OCA missions. Joint Pub 3-01.4 and AFDD 10 classify SEAD operations as campaign (AOR/joint operations area) air defense suppression, localized suppression, and opportune suppression.¹⁷⁰ The aerospace control depiction in figure 10 shows how SEAD fits into the overall aerospace

control effort. It is but a portion of the overall aerospace control role, but depending on the threat, it may necessitate the greatest effort initially from the JFACC.



Source: Frank Strickland, Jr. "It's Not About Mousetraps," *Joint Force Quarterly*, no. 13, Autumn 96, 93.

Figure 11. NRO Operations Value Model.

This study found two value models that specifically address the employment of military power in support of an operational mission. Figure 11 shows a model developed by the National Reconnaissance Office (NRO) that addresses military operations conducting an operational objective. The model is fairly generic since it describes not only an air mission, but it also applies to land and sea missions. The major drawback of the model is that it is not exhaustive in describing tasks and force qualities. For example, it does not adequately address the logistics and training issues necessary to properly employ functional forces.

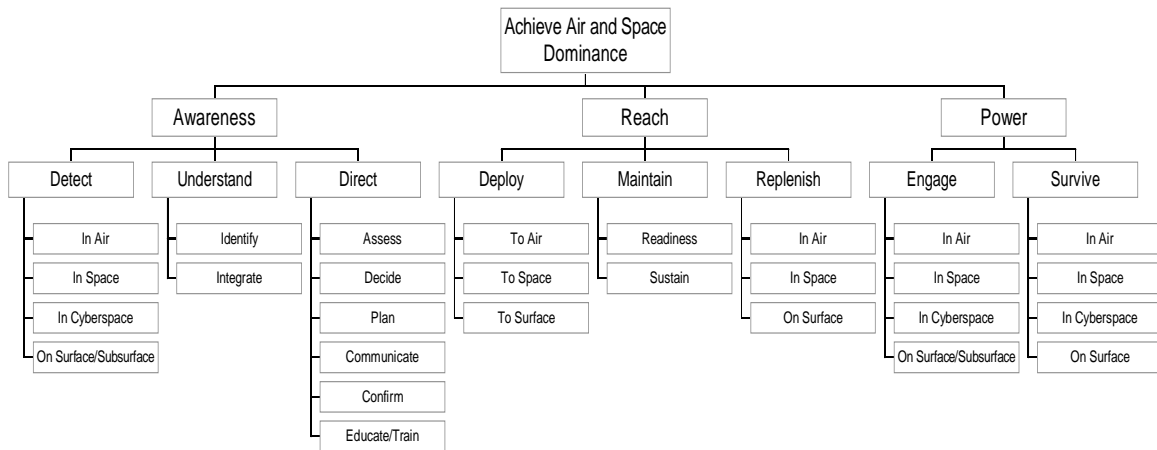
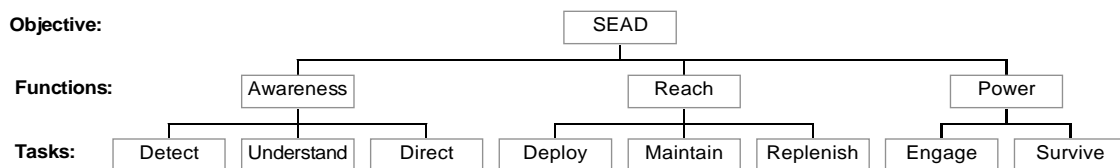


Figure 12. Foundations 2025 Value Model.

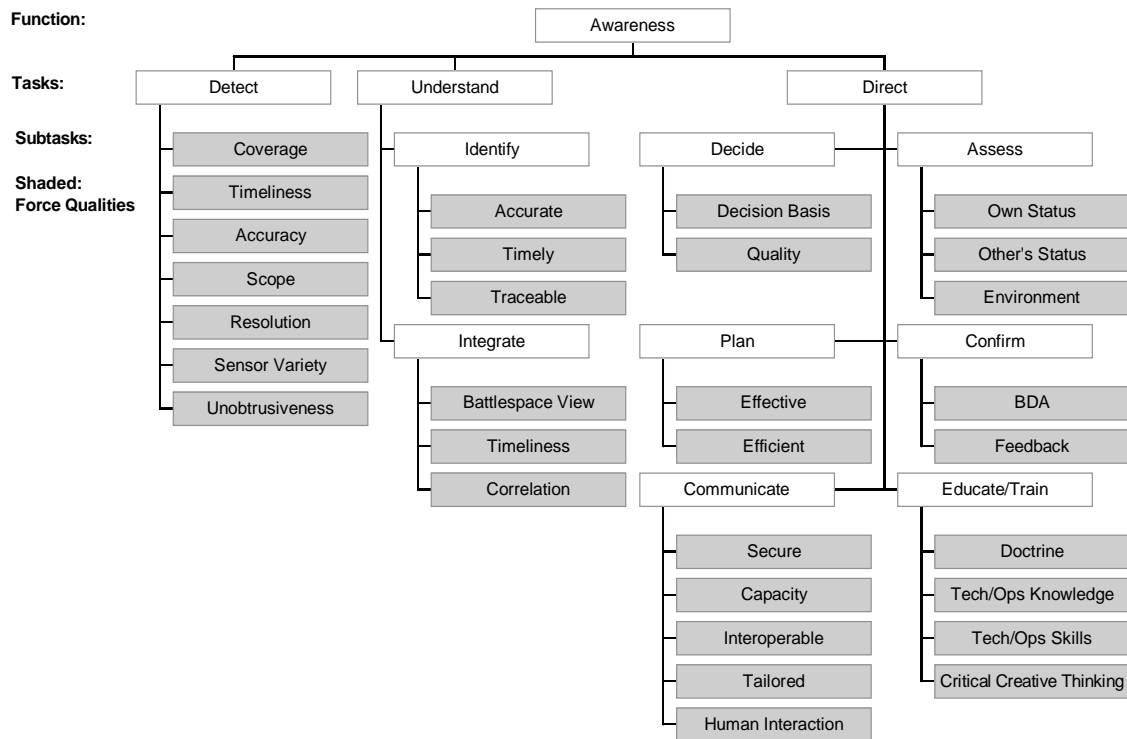
Another model, that specifically addresses the employment of air and space forces, is the Foundations 2025 Model. This model, developed by Air Force 2025 research at Air University provides a comprehensive collection of tasks, subtasks, and functions to perform an aerospace operational mission. Figure 12 shows only major tasks and subtasks. The complete model contains three functions, eight tasks, 29 subtasks, and 134 force qualities. Each of the force qualities contains a corresponding measure of merit and utility curve. Appendix A contains a complete list of subtasks, force qualities, and utility curves. This model provides a comprehensive collection of measures of merit and scoring functions to gain insight into a given operational objective.



Adapted from: Foundations 2025

Figure 13. SEAD Value Model—Functions and Tasks.

This study streamlined the Foundations 2025 model for SEAD analysis to provide a focused look at tasks specific to the SEAD mission. To streamline the model this study removed the distinction of separating environments between land, air, space, and cyberspace. The basic assumption underlying this reduction was that for the SEAD mission enemy systems reside on the ground, therefore the air, space, and cyberspace trees were eliminated from the Foundations model. The force qualities for these mediums are almost identical, so the separate distinctions clouded the issues of what is important to detect or engage a threat. By streamlining the foundations 2025 model the decision maker is forced to focus on force qualities, not platforms or mediums. Once streamlined, the Foundations 2025 model is very similar to the NRO model, except it presents a more comprehensive list of force qualities and utility functions.

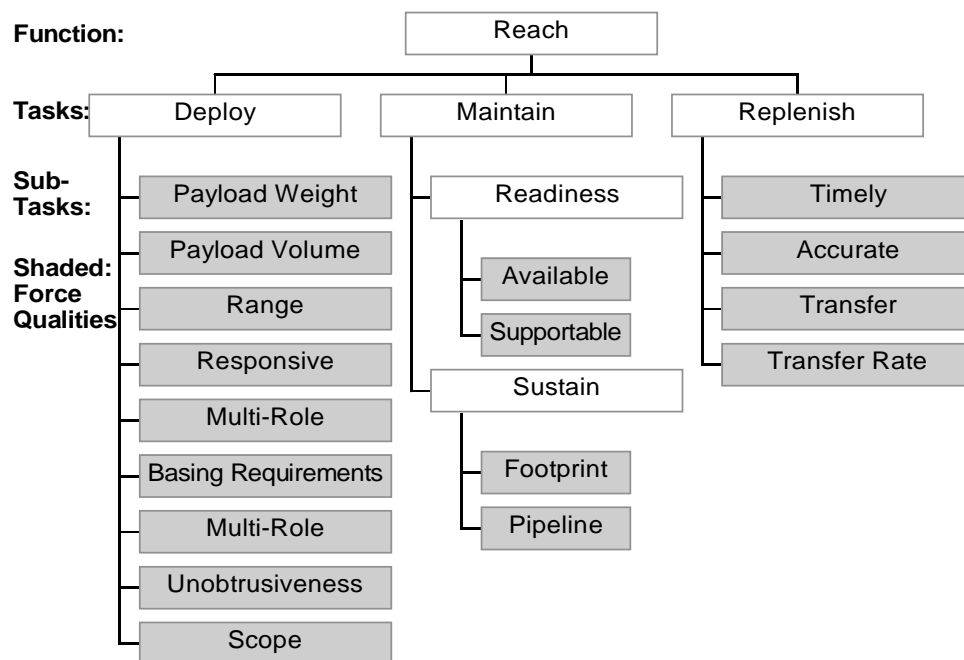


Adapted from: Foundations 2025

Figure 14. Awareness Tasks, Subtasks, and Force Qualities

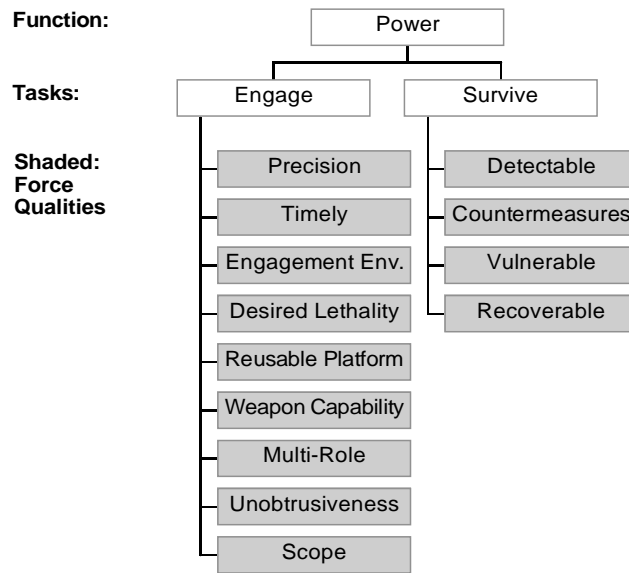
Figure 13 shows the SEAD value model used for this analysis. The top level functions and tasks are identical to the Foundations 2025 model. The lower layers, however, show the streamlining of subtasks and force qualities. Figure 14 shows the tasks, subtasks, and force qualities for the awareness function. Awareness is knowing, understanding, or cognizance of a situation through observing, detecting and identifying to facilitate directing and communicating an informed decision.¹⁷¹ Areas in the shaded boxes list the force qualities requiring utility curves.

Figure 15 depicts the value tree for SEAD's reach function. Reach provides the ability to expand the range or scope of influence while sustaining this influence by maintaining and replenishing.¹⁷²



Adapted from: Foundations 2025

Figure 15. Reach Tasks, Subtasks, and Force Qualities



Adapted from: Foundations 2025

Figure 16. Power Tasks, Subtasks, and Force Qualities

Finally figure 16 shows the value tree for the power function. Power, as defined here, is the ability to overtly or covertly affect, control, manipulate, deny, exploit, or destroy targets and the ability to survive while affecting targets.¹⁷³

These value trees provide the structure for understanding the complexity of the SEAD mission. This model breaks SEAD into its most basic elements and allows analysis of individual aspects contributing to the mission. By analyzing individual utility curves and weighing force qualities, subtasks, tasks, and functions, the decision maker presents a comprehensive framework establishing relationships between the value of each element as it relates to the whole process.

SEAD Force Qualities and Scoring Functions

To understand the nature of SEAD, this study concentrated on analyzing utility curves for SEAD force qualities. Specifically, the understand and detect tasks were

analyzed (figure 14). The purpose of this analysis was to understand the value of knowledge in conducting SEAD operations. An analysis of all 61 utility functions is beyond this study's scope. Additionally, since task weights are a function of the specific situation and commander's values, they will not be specifically addressed. To completely value model SEAD elements, the commander and staff should weigh each task and subtask to determine value and risk propensity for a specific situation.

The fundamental proposition of the value modeling is that it is possible to obtain a numerical expression for a decision maker's preferences. Foundations 2025 proves to be an excellent resource for exploring these preferences, except for the utility curve logic is left to the reader to determine. An important resource was lost by not defining the logic of the curves, and that is the goal here. By defining the logic, future decision makers can understand why variations exist in force quality values.

A team of experienced aircraft operators generated utility functions for the detect and understand tasks of awareness to determine the logic of utility curve shape. This study chose participants that had a high level of operational experience, especially those with combat experience. The following participated: Maj John Carter, A-10 Desert Storm, weapon school instructor; Maj Chris Chambliss, F-16; Maj Scott Grantham, USMC, AV-8, numerous small conflict operations; Maj Kent Laughbaum, F-15E, weapon school instructor; Maj Steve Seroka, F-15; Maj Scott Walker, F-16 Bosnia, weapon school graduate.¹⁷⁴ This study evaluated the consistency between the SEAD elicitation group and AF 2025 derived curves by comparing the general shape of the curves. Unless noted, the analysis compares SEAD curves with AF 2025 curves for "On Surface" force qualities. If a high level of consistency between the curves was seen, the study assumed

that similar logic defined the curves. If great inconsistencies existed, a SEAD user would have to perform elicitation sessions with area experts to adequately define utility values. The participants did not have access to the AF 2025 curves during the session. All curves were derived without knowledge of AF 2025 values. Measures of merit for the utility curves were generalized to protect classified information.

This research highlights significant lessons exposed by the elicitation session and utility curves. The SEAD elicitation group (SEAD-EG) evaluated force qualities across the phases of conflict, from planning to war termination. Unless noted in the figure, curve shape remained consistent throughout the phases.

Function: Awareness; Task: Detect; Force Quality: Coverage. The first force quality for detection was coverage. Figure 17 shows the Foundations 2025 utility function. The values of detection coverage reflects the global airpower outlook of AF 2025. The function reflects this outlook because systems that give only a regional detection capability rate poorly. A noteworthy finding is that the systems value rapidly decreases as the coverage area decreases.

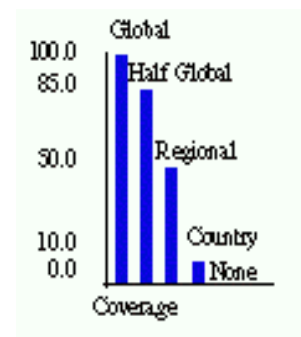


Figure 17. AF 2025 Coverage Utility Function

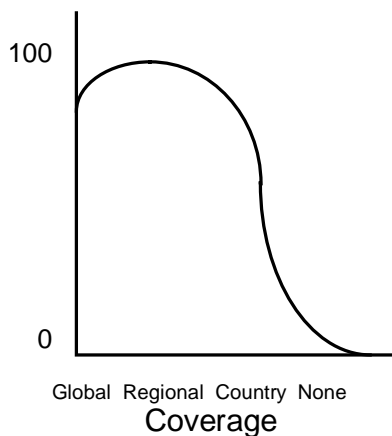


Figure 18. SEAD-EG Coverage Utility Function

The SEAD-EG derived curve, on the other hand, reflects the theater perspective of a JFACC staff providing SEAD planning. The curve reflects the regional nature of a JFACC staff, therefore globally capable systems score lower than ones that provide the essential capability. The SEAD-EG curve does show the same rapid decrease in score with smaller than regional detection capability. Additionally, SEAD elicitation group participants derived a curve reflecting a wide range of coverage versus the AF 2025 histogram.

The shape of the curve stays constant through the three types of SEAD. At the operational level, the SEAD-EG participants stated that they wanted to maintain regional detection capability. The type of SEAD had little impact on the size of detection area desired, though logically for a localized SEAD operation a smaller coverage area may be reasonable. Factors deciding coverage area included ingress and egress routing, and vulnerability outside the target area. With the curve in figure 18, the SEAD-EG felt that they would be able to adequately detect pop-up threats within the entire area of responsibility.

Function: Awareness; Task: Detect; Force Quality: Timeliness. Timeliness refers to the revisit rate of detection capability. Sensor detection capability drives the ability to get timely emerging information to decision makers. The measure of merit is time between sensor visits.

Figure 19 shows AF 2025 values for timeliness. High sensor revisit rate assumes a surveillance function, while 24 hour or greater rates show a propensity for reconnaissance. After a fairly short sensor revisit period, the AF 2025 discounts the

ability to detect. Apparently the goal of the group was to provide nearly constant detection capability.

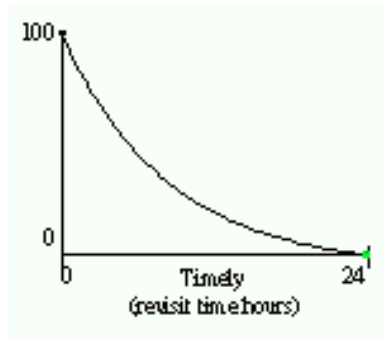


Figure 19. AF 2025 Timeliness Utility Function

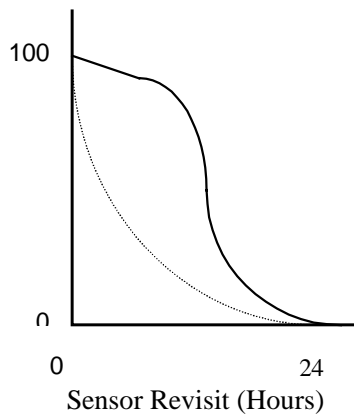


Figure 20. SEAD-EG Timeliness Utility Function

The SEAD elicitation group, on the other hand, made a distinction between the buildup and execution phases of the conflict. This group determined that in the buildup phase (solid line) a sensor visit rate was acceptable as long as it could detect changes in enemy status. For instance, in SEAD, target mobility determines sensor revisit rate necessary. A revisit rate inside this value is nearly as good as constant surveillance. Therefore, the curve drops off slowly at first, but a rapid decline occurs at the time where major threats can reposition. On the other hand, during the execution phase (dotted line),

the curve is close to the AF 2025 derived curve. Detection coverage in this phase needs to be nearly constant to counter any emerging threats.

Once again, the level of convergence between AF 2025 and the SEAD elicitation group is acceptable. The curves have the same basic shape, with the exception that the SEAD-EG has made performance tradeoffs, by phase of operations, in determining an acceptable level of criteria performance. Therefore, timeliness is a function of operations tempo. Sensor revisit rate should change with operations tempo to provide adequate information on a changing threat.

Function: Awareness; Task: Detect; Force Quality:
Accuracy. Accuracy is the ability of a sensor to pinpoint a detected target on the earth's surface using a suitable reference system. It is a measure of the pointing ability of the detector. Curves derived by the SEAD and AF 2025 elicitation groups were nearly identical with the exception that SEAD-EG participants defined accuracy with a continuous curve, while AF 2025 lumped accuracy figures into a histogram. Both figure's curves, however, reflect the fact that weapon system requirements drive accuracy needs.

For instance, the desire to detect an SA-2 accurately depends on what the air operations center does with that information. In the case of the SA-2, the detection accuracy only needs to be good enough to get the right weapon system to counter it. Both curves have a system

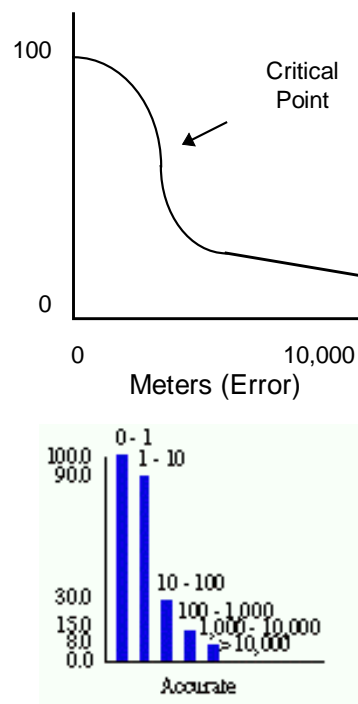


Figure 21. Accuracy Utility Functions

dependent critical point where the accuracy score rapidly declines. This curve remained constant over the duration of the war and regardless of the type of SEAD envisioned.

Only the requisite accuracy to target adversary threats is necessary from a detection system. Efforts to increase detection accuracy beyond weapons system capability provide only marginal returns.

Function: Awareness; Task: Detect; Force Quality: Scope. Scope is the amount of time that the a sensor may operate unrestricted by environmental conditions. For instance, the desired trend is for a given detection sensor to provide day/night all weather capability. Environmental conditions severely degrade many visual or infra-red sensors, even when positioned to provide accurate, timely coverage.

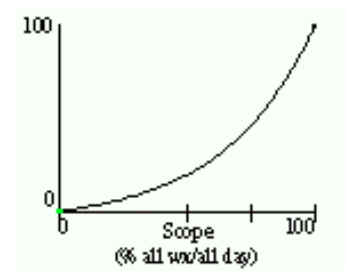


Figure 22. AF 2025 Scope Utility Function

AF 2025 groups rated scope as an increasing returns utility function. They scored it fairly low until the detection capability was nearly 100 percent of coverage. The 2025 group rated the need for all weather coverage as very important for detection.

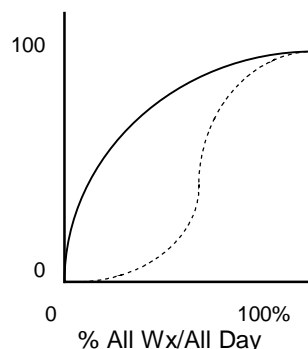


Figure 23. SEAD-EG Scope Utility Function

The SEAD elicitation group, conversely, rated scope as a diminishing return function. They stated that having any capability was important and the all weather

capability was a goal, not a hard requirement. In the buildup (solid line), or preparation phase of a conflict, the team thought that with time they would be able to fill holes missing from full time coverage. They did acknowledge that detection gaps would open them to surprise from the enemy, but they felt less concerned by the few all weather threat systems. Once war execution had begun (dotted line), however, the curve approaches the shape of the AF 2025 derived curve. The major difference is that the SEAD elicitation group acknowledged a diminishing return in pursuing 100 percent, all weather, all day coverage.

Function: Awareness; Task: Detect; Force Quality: Resolution. Resolution is the ability to tell an item's function once detected and to separate it from background or clutter. For example, with a low level of resolution a sensor might detect vehicles on a road. With increased resolution, tracked vehicles may be discernible. Finally, specific types of vehicles may be detected with better resolution.

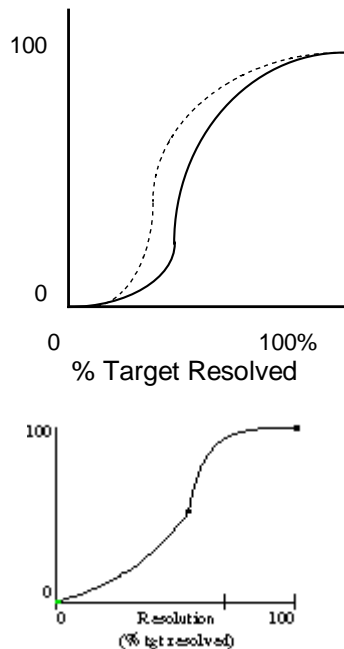
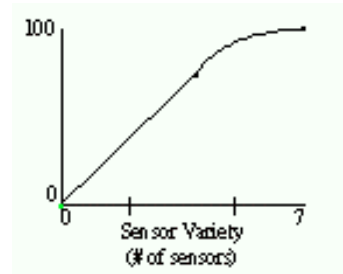


Figure 24. Resolution Utility Functions

AF 2025 and the SEAD-EG produced nearly identical resolution utility curves. Both groups admitted to desiring a certain level of resolution, after which returns were diminishing. The SEAD elicitation group additionally added that the resolution requirements increase once the commander commits forces to action (dotted line). They stated that increased detection resolution was necessary to rapidly sort friend from foe threats. This capability is to reduce detection ambiguity once shooting begins.

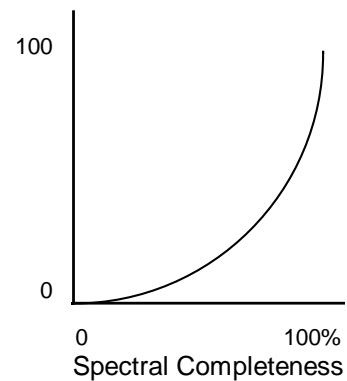


**Figure 25. AF 2025
Sensor Variety Utility
Function**

Only the requisite resolution to target adversary threats is necessary from a detection system. Efforts to increase detection resolution beyond that provide only marginal returns.

Function: Awareness; Task: Detect; Force Quality:

Sensor Variety. The spectral coverage force quality is the source of a major divergence between the SEAD and AF 2025 teams. The AF 2025 group rated sensor variety with a diminishing returns utility function. Although the AF 2025 reports do not explicitly state the logic, the curve shows that each additional sensor provides a marginal increase in detection capability. The utility curve in figure 25 shows such a function.



**Figure 26. SEAD-EG
Sensor Variety Utility
Function**

The SEAD elicitation group, on the other hand, linked spectral completeness with the ability for an adversary to hide undetected. Their curve shows increasing returns to 100 percent spectral coverage. They explain the curve logic using a stealth argument. An adversary will be unable to surprise U.S. forces with stealth capability if 100 percent of the electromagnetic spectrum is covered with sensor capability. On the other hand, gaps in spectral coverage provide areas where an adversary can develop systems for exploitation. The SEAD-EG logic argues that full spectral coverage can provide a force with information dominance. This information dominance prevents surprise on the battlefield.

Complete detection of the electromagnetic spectrum allows information dominance and prevents surprise on the battlefield. Stealth of any manner is not possible with

complete spectral coverage. Systems with stealth characteristics in one area of the electromagnetic spectrum will be detected in other areas of the spectrum.

Function: Awareness; Task: Detect; Force Quality: Unobtrusiveness. Another force quality where the AF 2025 and SEAD-EG curves greatly differed was on the unobtrusiveness force quality. Unobtrusiveness is the ability to detect enemy action or capability without his knowledge. Differing assumptions explains the difference between the curves. AF 2025 defines unobtrusiveness in detection as a positive quality, while the SEAD elicitation group rated it based on the desired effect.



**Figure 27. AF 2025
Unobtrusiveness Utility
Function**

AF 2025 rated unobtrusiveness with an descending S-curve. This curve reflects the traditional thinking that the best military advantage is gained when detection is unobserved. They suppose that unobtrusiveness provides a military advantage inherent for surprise. Infra-red search and track systems are examples of unobtrusive detection

systems.

The SEAD elicitation group curves reflect the JFACC's intent in his detection efforts. They claimed that a decreasing value curve was valid for surprise situations, but that a commander may want to use detection efforts to intimidate an enemy. The Wild Weasel mission is a classic example of this intimidation. During Desert Storm, Iraqi radars shut down due to the mere presence of an F-4G radar emission since they were so effective in targeting radars.¹⁷⁵ The intimidator values enemy knowledge of his detection efforts. The intimidation provides a deterrent effect.¹⁷⁶ The illuminating factor of the

curve is that stealth is not an enhancing characteristic and may not fulfill the commanders needs in some situations.

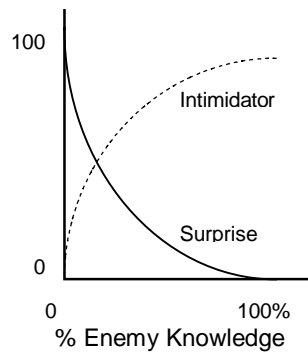


Figure 28. SEAD-EG Unobtrusiveness Utility Function

Unobtrusiveness is not always a positive force quality. Obtrusive detection efforts can have a significant deterrent quality. Stealth platforms performing SEAD may sometimes need to “show presence” to display total domination to an adversary’s forces.

Function: Awareness; Task: Understand; Subtask: Identify.

The data and processing requirements are greater to identify a threat or target than they are for mere detection. Force qualities for identification are accuracy, timeliness, and traceability.

Function: Awareness; Task: Understand; Subtask: Identify; Force Quality: Accurate. Accurate identification requires correctly identifying detected threats or systems. AF 2025 and the SEAD-EG placed a high value on the ability to accurately ID (figure 29). The AF 2025 curve is nearly

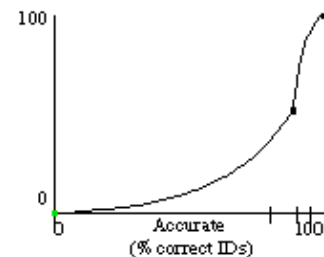
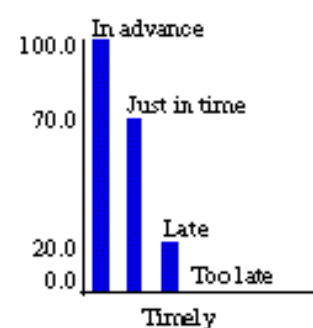


Figure 29. AF 2025 and SEAD-EG Accurate Utility Function

placed great emphasis on accurate identification. Conversely, information that was less

than 80 percent accurate scored fairly poorly. According to the SEAD elicitation group, the point of inflection depends on the type of war and lethality of environment. For instance, for a peace operation or limited military operation, ROE usually dictates accurate ID before weapon employment. During medium to high intensity conflict, on the other hand, ROE usually allows looser weapon employment. These differing environments change the point where the curve rapidly rises.

Function: Awareness; *Task:* Understand; *Subtask:* Identify; *Force Quality:* Timely. Just as in detection, information is of little value if it does not arrive in time to affect a decision. The shapes of the curves are very similar to the utility of timeliness in detection.



The AF 2025 groups provided a histogram that reflects importance in early identification. The function rapidly decreases as identification is too late to affect a battle decision.

**Figure 30. AF 2025
Timely Utility
Function**

Figure 30 shows the AF 2025 function. The function appears to be a linear relationship with each step in lateness providing a linear decrease in score.

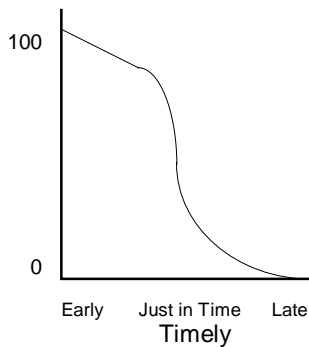


Figure 31. SEAD-EG Timely Utility Function

The SEAD elicitation group provided a utility curve that also reflects the need for timely information. The function shows a rapid decrease after the “just in time” value. They made the function a linear decrease initially, however, to stress that efforts to ensure early

identifications are worthwhile. The group stressed that although “just in time” was good enough in most cases, they would invest resources to provide earlier identification. In fact, they purposely made the function linear initially to show that the increased identification time provides a corresponding increase in value.

Function: Awareness; Task: Understand;
Subtask: Identify; Force Quality: Traceable.
 Traceability is the ability to track the source of the information thereby providing confidence in the data. The assumption underlying traceability is that

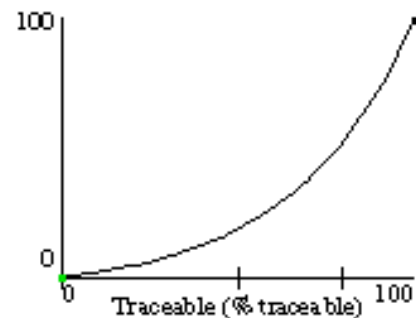


Figure 32. AF 2025 and SEAD-EG Traceable Utility Function

the dependability of the information is highly dependent on its source. If early warning data from a system with high false alarm rates is not traceable within an air defense system, that data could cause bigger problems as higher levels integrate it. The decision maker’s confidence in the presented information is dependent on its traceability.

Both the AF 2025, and SEAD elicitation groups, present curves showing increasing returns for increasing traceability. The SEAD elicitation group stated that accountability

for data made it more predictable and believable. Data from known sources is preferred over unknown or marginal data.

Function: Awareness; Task: Understand; Subtask: Integrate.

Another subtask under the understand task is the ability to integrate the information to provide a fused view of the battlefield. The objective of the fused battlefield view is to derive more information through combining sources, than is present in any individual element of input data. Integration provides a synergy of enhancing each individual sensor's effectiveness.¹⁷⁷ This ability requires the force qualities of battlespace view, timeliness, and correlation.

Function: Awareness; Task: Understand; Subtask: Integrate; Force Quality: Battlespace View. Battlespace view is the definition of the relevance of information provided to the operational commander. The commander needs a view which is relevant without being flooded by unnecessary information. Clausewitz, in *On War*, warned against the blizzard of irrelevant data in war, distracting the judgment of the commander.¹⁷⁸

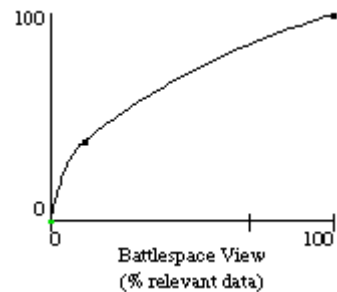
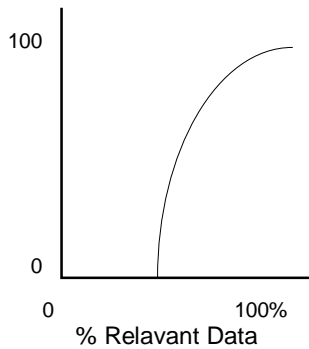


Figure 33. AF 2025 Battlespace View Utility Function

Figure 33 shows the AF 2025 utility curve for battlespace view and its corresponding measure of merit, percentage of relevant data. The curve initially slopes steeply, then becomes nearly linear from 10 percent to 100 percent. The curve suggests that any increase in relevance provides a proportionate increase in battlespace view.



**Figure 34. SEAD-EG
Battlespace View
Utility Function**

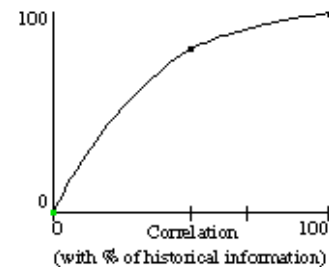
The SEAD elicitation group derived curve in figure 34 shows nearly the same curve for data relevance, with the exception that the relevancy standard is much higher. They stated that the battlespace view was fairly useless until a minimum standard of relevancy was reached. Until that point, the value of the function is zero. Once a significant amount of relevant data is available the curve rises very steeply until a point of diminishing returns is reached. The group specifically wanted to score poorly situations where the majority of the information was irrelevant. They thought that without a large percentage of relevant data understanding would be severely degraded.

Function: Awareness; Task: Understand; Subtask: Integrate; Force Quality: Timeliness. Just as in detection and identification, timeliness is a critical integration quality. Integrated information has little value if it arrives too late to affect a crucial decision situation. Like the earlier timeliness utility curves (figures 30 and 31) both SEAD and AF 2025 elicitation groups showed rapidly declining values for late arriving information. Once again AF 2025 showed a fairly rapid decrease in value, while the SEAD elicitation group valued the importance of improving the timeliness of information.

Function: Awareness; Task: Understand; Subtask: Integrate; Force Quality: Correlation. One of the major problems with information can be the lack of correlation. Pilots, during Desert Storm complained, about threat maps being clogged with uncorrelated information. Numerous threat sites were depicted on maps, even though

crews determined the sites were disabled or reported incorrectly. No system functioned to remove threats from the maps. Finally pilots ignored threat information because of too many inaccurate missile sites were depicted. Intelligence had failed to correlate threat reports from numerous sources, as well as marking sites targeted and destroyed earlier.¹⁷⁹

AF 2025 and SEAD elicitation groups showed some divergence in the correlation force quality. AF 2025 shows a diminishing returns curve for the ability to correlate properly new information with historical data. The SEAD elicitation group, conversely, put much more emphasis on the negative value of poorly correlated information. They placed increased emphasis on properly correlated data by forcing a very steep slope to the curve. They acknowledged diminishing returns in attempting



**Figure 35. AF 2025
Correlation Utility
Function**

100 percent correlation, but placed more emphasis on a high level of correlation. They also had a strong aversion to poorly correlated data. Like the relevancy function, they forced poor utility scores on poorly correlated information. Their intent was to insure that information provides a realistic view of the theater situation. For instance, if several sensors detected and identified one threat, they wanted it fused into a single report. With poor correlation the same threat could be reported several times, providing a false view of the real situation.

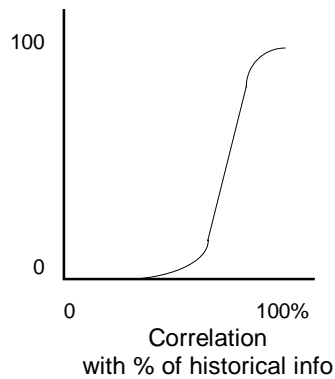


Figure 36. SEAD-EG Correlation Utility Function

Poorly correlated data contributes to the “fog and friction” of war rather than reducing it. Data fusion efforts require a significant degree of correlation to provide a synergistic view of the battlespace.

Summary

Value modeling provides an instrument for breaking a complex problem into its constituent parts for analysis. By fracturing a complex problem into individual parts, the decision maker can better understand all elements that make an operational art task. Additionally, utility function scoring provides an opportunity for planners and decision makers to understand assumptions and tradeoffs inherent in the measures of merit and force qualities underlying an operational objective.

The scoring function analysis provides insight into the details of SEAD information requirements. The SEAD elicitation group found the scoring exercise useful in determining tradeoffs between differing measures of merit. For instance, the curves provided a basis for tradeoff analysis when two or more of the force qualities conflicted. Additionally, the scoring function itself helped capture the logic of the value of each function as it fits in the whole. Elicitation sessions forced experienced operators to

articulate and defend logic for curve shape. This logic provided insight into the information requirements to perform SEAD.

The SEAD elicitation group forced no changes to the curves depending on the type of SEAD desired. In all cases, the scoring functions were the same for campaign, localized, and opportune SEAD. The nature and phase of the war, on the other hand, changed several scoring functions. Once again, this provides insight to the planner on how the nature and phase of conflict change the mission tasks.

Specific lessons derived from the utility curve analysis were:

Task: Detect

Force Quality: Coverage. Minor Finding: Detection systems lose value unless they provide coverage over the entire area of operations. Without this coverage, the commander is vulnerable to surprise from the adversary. On the other hand, greater than regional coverage provides the commander with little additional value.

Force Quality: Timeliness. Minor Finding: Timeliness is a function of operations tempo. Sensor revisit rate should change with operations tempo to provide adequate information for the rate the threat can change.

Force Quality: Accuracy. Major Finding: Only the requisite accuracy to target adversary threats is necessary from a detection system. Efforts to increase detection accuracy beyond weapons system capability provide only marginal returns.

Force Quality: Scope. Minor Finding: Commanders desire all weather capability in information gathering systems, but until the execution phase of a conflict, less than 100 percent coverage is adequate. Once forces are committed to action, or hostilities are imminent, increased scope is desired.

Force Quality: Resolution. Major Finding. Only the requisite resolution to target adversary threats is necessary from a detection system. Efforts to increase detection resolution provide only marginal returns.

Force Quality: Sensor Variety. Major Finding. Complete detection of the electromagnetic spectrum allows information dominance and prevents surprise on the battlefield. Stealth of any manner is not possible with complete spectral coverage.

Force Quality: Unobtrusiveness. Major Finding. Unobtrusiveness is not always a positive force quality. Obtrusive detection efforts can have a significant deterrent quality. Stealth platforms sometimes need to “show presence” to display total domination to an adversary’s forces.

Task: Understand; Subtask: Identify

Force Quality: Accuracy. Minor Finding. The requirement for accurate identification depends on the type of war and lethality of environment. Intensity of conflict and rules of engagement drive requirements for identification accuracy.

Force Quality: Timely. Minor Finding. The value of threat identification rapidly decreases once the decision situation is reached. Late information has little or no value. Early identification of adversary threats enhances effectiveness and these efforts are worthwhile to the strategist.

Force Quality: Traceable. Minor Finding. Data accountability made it more predictable and believable. Data from known sources is preferred over unknown or marginal data because it increases the decision maker’s confidence in the presented information.

Task: Understand; Subtask: Integrate

Force Quality: Battlespace View. Minor Finding. Irrelevant data skews the commander's view of the battlespace. Until a high standard of relevant information is reached, the commander is distracted with information that lends no insight into the conflict.

Force Quality: Timeliness. Minor Finding. One again late information, at any stage of the information gathering process, is relatively useless to the strategist. Information systems should provide relevant information in a timely manner. Additionally, the strategist must prioritize his information needs to ensure timely receipt of desired information.

Force Quality: Correlation. Major Finding. Poorly correlated data contributes to the "fog and friction of war" rather than reducing it. Data fusion efforts require a significant degree of correlation to provide a synergistic view of the battlespace.

To understand the dynamic nature of SEAD and value tradeoffs, utility curve analysis is necessary for the remaining force qualities. The analysis above provides insight only into the complexity of SEAD information needs.

Although the utility functions did not change, the SEAD elicitation group stated that the tree weights would change depending on the type of SEAD. As shown on the notional model (figure 9), the weights of tasks and subtasks are weighed due to reflect the decision makers values in accomplishing the main objective. In the SEAD case, the group felt that the decision maker's weights for awareness, reach, and power, and their tasks and subtasks, would change depending on the nature of the task.

Notes

¹⁵⁰¹⁵⁰ Ralph L. Keeney, "Using Values in Operations Research," *Operations Research* 42, no. 5 (September-October 1994), 795.

¹⁵¹ Joint Pub 3-56.1, *Command and Control of Air Operations*, 14 November 1994, III-3.

¹⁵² Air Force Doctrine Document 2, *Theater Air Warfare*, Fourth Draft, 21 May 1996, 7-11.

¹⁵³ Strategy-to-task methodology is aimed to provide guidance to weapons acquisition choices and to provide an audit trail from weapon to strategy and national goals. For the campaign planner it is a useful method for auditing tasks in support of a given strategy, but provides little guidance by itself on the prioritization of tasks and assets. Glenn A. Kent, and William E. Simons, *A Framework for Enhancing Operational Capabilities*, (Santa Monica: RAND, 1991) 8-15. The "meat" is the assessment of the adequacy of force elements and tradeoffs between elements. Of particular interest are resources with no identifiable impact on objectives. Leslie Lewis, and C. Robert Ball, *Strategy-to-Tasks: A Methodology for Resource Allocation and Management*, (Santa Monica: RAND, 1993), 25.

¹⁵⁴ Lt Col Jack A. Jackson, Jr., Ph.D., et. al., "An Operational Analysis for Air Force 2025: An Application of Value-Focused Thinking to Future Air and Space Capabilities," AF 2025 Research Report Vol. 4, Chapter 3 (Maxwell AFB, AL: Air University, May 1996), 32-33.

¹⁵⁵ Frank B. Strickland, Jr., "It's Not About Mousetraps -- Measuring the Value of Knowledge for Operators," *Joint Force Quarterly*, no. 13 (Autumn 1996), 90-94.

¹⁵⁶ In a book review for *Interfaces* magazine Benjamin Lev lists *Value-Focused Thinking: A Path to Creative Decisionmaking* as a "must read" for executives and operations research practitioners. *Interfaces* 23, no. 6 (November-December 1993) 140-142. Numerous business and operations research professors give value-focused thinking high reviews in *Sloan Management Review* 36, no. 1 (Fall 1994), 4-5.

¹⁵⁷ Ralph L. Keeney, *Value Focused Thinking: A Path to Creative Decisionmaking*, (Cambridge, Mass.: Harvard University Press, 1992), 33.

¹⁵⁸ Keeney, "Using Values in Operations Research," 794-795.

¹⁵⁹ Jackson, 11.

¹⁶⁰ Keeney, *Value Focused Thinking*, 112.

¹⁶¹ Jackson, 11-12.

¹⁶² Area experts can be asked to graph measures of merit to generate curves for value judgments of criteria performance. Paul C. Nutt, *Making Tough Decisions*, (San Francisco: Jossey-Bass Publishers, 1989), 494-501.

¹⁶³ Lawrence Lapin, *Quantitative Methods For Business Decisions With Cases*, 4th ed., (New York: Harcourt Brace Jovanovich, Publishers, 1988), 710-712.

¹⁶⁴ Nutt, 467-504.

¹⁶⁵ Ibid., 494-495.

¹⁶⁶ Nutt provides techniques for eliciting decision makers weights. Ibid. 411.

¹⁶⁷ Ralph L. Keeney, "Structuring Objectives for Problems of Public Interest," *Operations Research* 36, no. 3 (May-June 1988), 403-404.

Notes

¹⁶⁸ The scoring example is adapted from the AF 2025 Operations Research report. Jackson, 14-16

¹⁶⁹ AFM 1-1, *Basic Aerospace Doctrine of the United States Air Force*, Vol. I, March 1992, 10.

¹⁷⁰ AFDD 10, *Counterair Operations*, Final Draft, 1 September 1996, 4, 20.

¹⁷¹ Jackson, 27.

¹⁷² Ibid., 28.

¹⁷³ Ibid., 28.

¹⁷⁴ In addition to operational experience, all participants completed two years of study specializing in airpower application at the operational level of war. Although the participants have significant academic study at this level of war, they have limited actual experience in an Air Operations Center. Group size was limited below 10 to ensure active participation by all participants. Nutt, 225-226.

¹⁷⁵ The goal of the coalition SEAD effort was to dominate the Iraqi hearts and minds. Strategists wanted the Iraqi operators to fear emissions with coalition aircraft nearby. After the first day of the war, HARM shooting aircraft had a deterrent effect on Iraqi radar operators, Iraqis turned off their radars when HARM-carrying aircraft were in the vicinity. Maj Gen John Corder (Ret) , CENTAF Deputy for Operations, interviewed by author, 15 April 1997. Thomas A. Keaney and Eliot Cohen, *Revolution in Warfare? Air Power in the Persian Gulf*, (Annapolis: Naval Institute Press, 1995), 195-196.

¹⁷⁶ The initial SEAD campaign in Desert Storm made Iraqi defenses seem impotent, significantly increasing the F-4G's deterrent value. Stephen T. Hosmer, *Psychological Effects of U.S. Air Operations In Four Wars 1941-1991*, (Santa Monica: RAND, 1996), 174.

¹⁷⁷ Edward Waltz and James Llinas, *Multisensor Data Fusion*, (Norwood, MA: Artech House, Inc., 1990). 1-2. Mark Hewish, "Sensor Fusion for Air Defense," *International Defense Review* 26, no. 4, 334-336.

¹⁷⁸ Carl von Clausewitz, *On War*. (Princeton, N.J.: Princeton University Press, 1989), ed. and trans., Michael Howard and Peter Paret, 117-118.

¹⁷⁹ Maj John Carter, Desert Storm A-10 pilot, interviewed by author, 29 April 1997. Maj Phil Smith, Desert Storm F-111 pilot, interviewed by author, 28 April 1997.

Chapter 5

Conclusion

Air control can be established by superiority in numbers, by better employment, by better equipment, or by a combination of these factors.

—Carl “Tooey” Spaatz

Ground defenses are more potent than ever envisioned by Mitchell or Douhet, but airborne countermeasures eventually reign supreme in the quest for air superiority. Airpower provides flexibility unmatched by any ground defense. On the other hand, ground-based defenses have been able to inflict horrific losses on airborne attackers. The German defense of Schweinfurt, and Syrian defense of the Golan Heights are but two examples of the threats airmen must face. Airmen should neutralize surface defenses during the opening phases of a war, providing an environment for the exploitation of air superiority.

The nature of SEAD changes with differing threats, and countering technologies. Many SEAD professionals envision it only in the terms of suppressing defenses with HARM missiles.¹⁸⁰ But with advancements in technology and doctrine, defense suppression has become much more flexible.¹⁸¹ This study of SEAD provides a foundation for training the planner’s mind for thinking about the nature of defense suppression and countering changing threats.

This study showed how SEAD operational objectives change with the nature and maturity of an air campaign. Historical analysis provided the backdrop for understanding the development of SEAD capability while highlighting its evolution from a reactive to a proactive measure. This section furnished a foundation for studying SEAD objectives and strategy. Next, an air defense system evaluation provided understanding of the target and how system operations change depending on the control mechanism. The analysis provided insight into high payoff objectives depending on the nature of the threat. Finally, this study performed a value-model analysis on SEAD information gathering tasks to quantify a small portion of airpower force qualities inherent in a SEAD operation. Motivation for building and evaluating the SEAD model was to lend some insight into the mission's complexity, while complementing the commander's intuitive thinking. Combined, these discussion areas highlighted the nature of SEAD and provided a source document for discussing SEAD strategy.

Limitations

Two factors limited the scope of this study; classification and the complexity of the mission. First, the goal of this study was to provide insight on SEAD to audiences not privy to classified information. This study considers SEAD without emphasis on individual systems to allow discussion in an open forum. Traditionally, papers involving defense suppression remain classified due to the analyses of particular systems and capabilities. This study aimed at macro level discussion of notional defenses to allow free discussion of the topic. Any true SEAD situation will involve much more complex scenarios requiring in-depth, and classified, system analysis. Second, this study

attempted to capture the nature of SEAD by value-modeling its functions, providing insight into force qualities and measures of merit. Due to space and time limitations, this research analyzed the detection and understanding subtasks only, for insight on how they affect an operational mission. Further analysis on the remaining awareness, reach, and power force qualities will allow consideration of other value tradeoffs. Additionally, the Foundations 2025 model should be wargamed to document the worth of its established collection of utility curves.

Practice

The collection of historical development, air defense system analysis, and value-modeling provides insight to train the mind of the commander on what to expect when operations begin. Maj Gen John Corder, CENTAF Deputy for Operations during Desert Storm offered his insight into the nature of a SEAD operation. He considered the intelligence preparation of the battlefield to be excellent, due primarily to the time offered in the 6 month buildup. He felt confident on the first night of the war that he knew how the Iraqi IADs operated, and the effect he attempting to impose on it. After several days into the war, however, everything seemed chaotic. He had no confidence in the picture of the Iraqi IADs. After several days of worry, he decided that chaos must be the IADs picture that a successful campaign should see. The successful dismantling of Iraqi IADs command and control combined with the fog of war presented a confused battle picture. Gen Corder reasoned that if intelligence could adequately describe Iraqi operation then he probably did not affect the system sufficiently. The coalition successfully attacked the air defenses and drove them into chaotic, autonomous operations. His measure of success

was aircraft attrition rates. As long as rates were low, he considered himself successful. He also considered the number of SAM launches as a measure of merit because he aimed to totally dominate and intimidate the air defense operators. Infrequent or unguided launches were seen as success.¹⁸² Historical study, defense system analysis, and value modeling provide the tools for the commander for framing battlefield decisions.

Gen Corder's scenario highlights the dynamic nature of war and the complexity of the environment. This study has provided a view into the complexities of SEAD, and hopefully will offer insight to future planners on how to develop an effective suppression strategy.

Notes

¹⁸⁰ Several articles and GAO reports question the Air Force commitment to the SEAD effort while it emphasizes other less important missions. Commander Kenneth G. Krech, "The Navy Must Suppress Enemy Air Defenses," *Proceedings* 121, no. 10 (October 1995), 76-79. John Knowles and Zachary Lum, "Into the Readiness Gap," *Journal of Electronic Defense* 19, no. 3 (March 1996), 46-51. General Accounting Office, *Combat Air Power: Funding Priority for Suppression of Enemy Air Defenses May Be Too Low*, GAO/NSIAD-96-128 (Washington D.C.: General Accounting Office, April 1996), *Suppression Of Enemy Air Defenses: Air Force Plans*, GAO/NSIAD-93-221, (Washington D.C.: General Accounting Office, September 1993).

¹⁸¹ With the introduction of stealth, combined with GPS guided precision munitions, the nature of SEAD will likely change away from missile engagements with threat radars. Zachary A. Lum, "Air Force Lethal SEAD: Goodbye Weasel...Hello Shark," *Journal of Electronic Defense* 17, no. 2 (February 1994), 34-39.

¹⁸² Maj Gen John Corder (Ret), CENTAF Deputy for Operations, interviewed by author, 15 April 1995.

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